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CONTRIBUTIONS TO OCEANOGRAPHY AND FISHERIES BIOLOGY

BYDRAE TOT OSEANOGRAFIE EN VISSERYBIOLOGIE

CAPE TOWN KAAPSTAD

1979

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CONTENTS/INHOUD

BEST, P. B. and P. D. SHAUGHNESSY — An independent account of Captain Benjamin Morrell's sealing voyage to the south-west coast of Africa in the *Antarctic*, 1828/29 1

SHAUGHNESSY, P. D. and A. I. L. PAYNE — Incidental mortality of Cape fur seals during trawl fishing activities in South African waters 20

PAYNE, A. I. L. — A survey of the stock of the southern African West Coast sole *Austroglossus microlepis* between 28°30'S and 32°S . . 26

NEPGEN, C. S. DE V. — Trends in the line fishery for snoek *Thyrsites atun* off the South-Western Cape, and in size composition, length-weight relationship and condition 35

DA FONSECA BAPTISTA, S. R. — Changes in abundance of albacore *Thunnus alalunga* and yellowfin *T. albacares* off southern Africa, 1969-1976 44

VENTER, J. D. — 'n Verbeterde tegniek vir die brand van heel otoliete 49

LE CLUS, F. — Oocyte development and spawning frequency in the South West African pilchard *Sardinops ocellata* 53

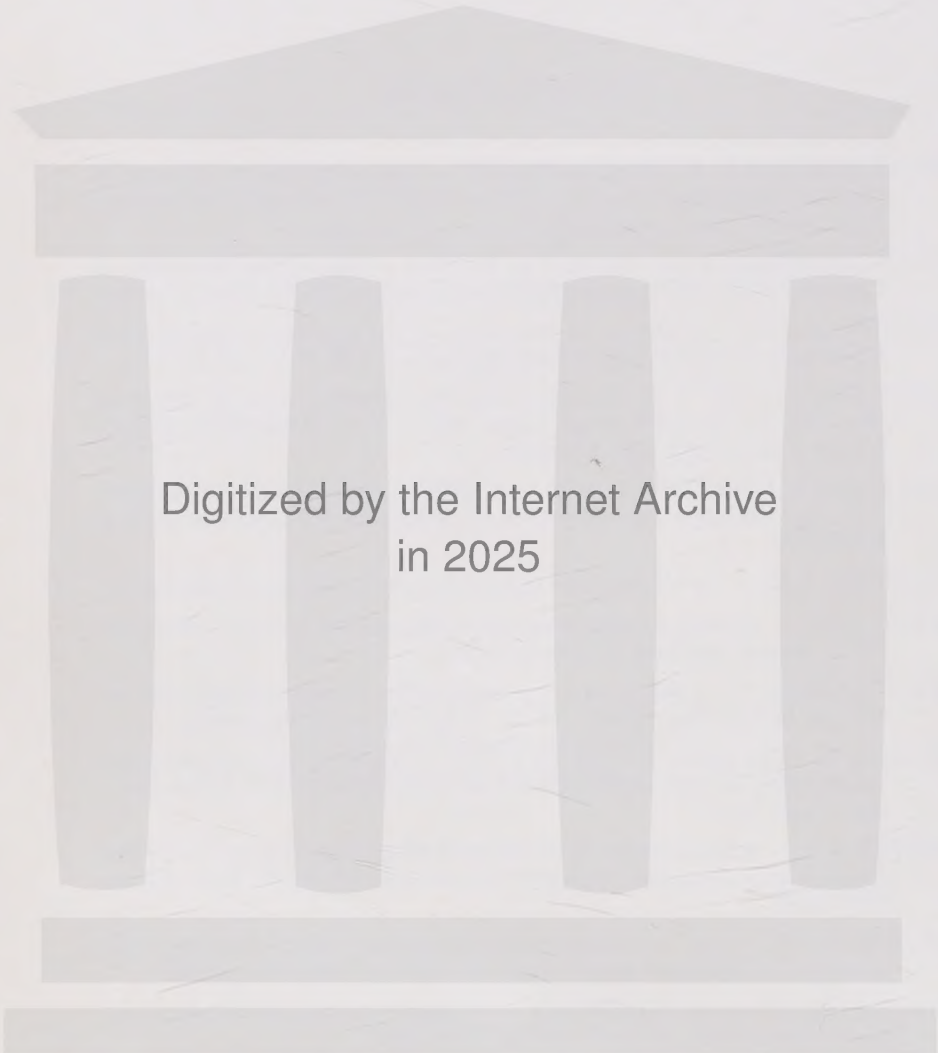
DE VILLIERS, G. — Recovery of a population of white mussels *Donax serra* at Elands Bay, South Africa, following a mass mortality . . 69

POLLOCK, D. E. and C. J. DE B. BEYERS — Trap selectivity and seasonal catchability of rock lobster *Jasus lalandii* at Robben Island sanctuary, near Cape Town 75

BOYD, A. J. — A relationship between sea surface temperature variability and anchovy *Engraulis capensis* recruitment off South West Africa, 1970-1978 80

ROBERTSON, A. A. — Adaptations permitting aimed trawling with rectangular midwater trawls from non-fishery research vessels . . 85

LAZARUS, B. I. and D. DOWLER — Pelagic tunicata off the west and south-west coasts of South Africa, 1964-1965 93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1979

AN INDEPENDENT ACCOUNT OF CAPTAIN BENJAMIN MORRELL'S SEALING VOYAGE TO THE SOUTH-WEST COAST OF AFRICA IN THE *ANTARCTIC*, 1828/29

P. B. BEST and P. D. SHAUGHNESSY

A comparison of Morrell's published account with that in the hitherto unpublished journal of a crew member of the *Antarctic* reveals differences in the timing of events on the voyage, omissions of apparently significant occurrences by Morrell, and elaboration, exaggeration or fictionization of events by Morrell. The journal also provides evidence for the existence of certain seal colonies and the absence of others that had existed previously or are known to exist now. From this evidence, seal abundance on the West Coast must have been much less than it is now, with the apparent absence of all the large mainland herds that exist today.

'n Vergelyking van Morrell se gepubliseerde relaas met dié in 'n tot nog toe ongepubliseerde dagboek van 'n bemanningslid van die *Antarctic* bring verskille in die tydsbepaling van gebeure op die vaart, weglatings van skynbaar betekenisvolle voorvalle deur Morrell, en uitbouing, oordrywing of versinsel van gebeure deur Morrell aan die lig. Die dagboek verskaf ook getuienis vir die bestaan van sekere robkolonies en die afwesigheid van andere wat voorheen bestaan het of waarvan die huidige bestaan bekend is. Volgens hierdie getuienis moes die robbe aan die Weskus veel minder volop as tans gewees het, en al die groot kuddes wat vandag op land bestaan, moes ontbreek het.

The South African fur seal *Arctocephalus pusillus* has been commercially exploited for about 370 years, a Dutch expedition taking 45 000 animals near the Cape of Good Hope between March and October 1610 (Hart 1957).

Despite this long history, the authors are aware of only two published accounts of commercial sealing operations on the coast of southern Africa prior to 1900 (Allyn 1879, Morrell 1832). Of these, Morrell's has received far greater publicity, due in part to the discoveries that he claimed to make and because of the controversial nature of the account of this and his other voyages.

The schooner *Antarctic* (172 tons) left New York on 25 June 1828, bound for the south-western coast of Africa, with a complement of 23 men captained by Benjamin Morrell, Jr. It returned to New York on 14 July 1829. This was the third of four voyages described with only minor alterations by Morrell (1844b) and in part by Morrell (1844a). Neither of these adds to the original account of 1832.

The interest created by Morrell's account of this voyage arose mainly because of the mention of extensive guano deposits on Ichaboe Island (leading ultimately to the "guano rush" of 1843-45 — Watson 1930) and his description of an apparently massive die-off of seals on Possession Island (and to a lesser extent on Seal and Penguin Islands). Furthermore, his descriptions of much of the West Coast, including sailing directions and observations of natural features, were sufficiently detailed and original to feature in successive editions of the Africa Pilot published by the Hydrographic Department of the Admiralty. Unfortunately, many of the statements that Morrell made in his book have been the subject of much subsequent discussion, and some authors have seriously questioned his veracity (e.g. Eden 1846, p. 8; Andersson 1861, p. 273; discussion in Hamilton 1870).

In September 1977, an independent account of Morrell's 1828/29 and 1829-31 voyages in the *Antarctic* (his third and fourth voyages) was found in the G. W. Blunt White Library at Mystic Seaport, Mystic, Connecticut, U.S.A. (log-book no. 339). The accounts of these two voyages were the first in a single volume which contained the manuscript journals of several voyages in different vessels. According to the librarian, this volume was purchased from a dealer in 1965. The authorship of the accounts of both *Antarctic* voyages could not be determined directly because the journals were unsigned. The third voyage in the volume was signed John W. Keeler. Comparison of his handwriting with that in the previous two journals was inconclusive. However, in the published account of his 1829-31 voyage, Morrell mentions a John Keeler as being one of the seamen wounded in a skirmish with natives at the "Massacre Islands" (4°50½'S, 156°10½'E) on 28 May 1830 (Morrell 1832, p. 414). It is therefore highly likely that the author of both *Antarctic* journals was John Keeler, and this assumption has been made throughout this report.

The journals of both *Antarctic* voyages are in good condition and clearly written, and John Keeler gives the impression of having been a methodical

and unemotional observer. There would be obvious historical value in a thorough comparison of Keeler's and Morrell's accounts of the whole of both voyages, but for the purposes of this report, the comparison has been confined to the section of the 1828/29 voyage when the *Antarctic* was sealing on the African coast, using Morrell's (1832) account for the comparison.

In addition, Keeler's journal is invaluable for the original information it gives on the distribution of seals along the coast (including the size of daily catches from particular colonies), the tactics of nineteenth-century sealers, and the presence of other vessels similarly engaged on the African coast.

In considering the quotations given from Keeler's journal, it should be noted that, in the first half of the nineteenth century, it was customary on merchant vessels for the day at sea to begin and close at noon, so that the sea day was 12 hours ahead of civil time (Bertrand 1971, p. 49). Thus, an incident recorded in the journal as occurring at 10 pm on 2 October would in reality have occurred at 10 pm on 1 October on the civil calendar. All dates given below refer to civil time except when included in direct quotations.

A microfilm copy of Keeler's journal for 1828/29 is now at the South African Library, Cape Town (microfilm no. M2595).

ANTARCTIC ON THE AFRICAN COAST

The schooner made its first landfall on the African coast at Saldanha Bay on 4 September 1828 at the beginning of a sealing voyage which lasted until 27 May 1829 (see Figure 1 for location of place names mentioned in the text).

> ". . . At 8 AM came to anchor in saldanhar bay in 3 fathoms of Water sandy bottom 9 AM one boat started in search of water And one in search of eggs and bullock . . . saw many birds of different kinds and got a Few eggs from the nests of shags the other birds had not began To lay . . ."

The search for seals soon began.

> "Friday September 5th . . . 5 AM the boat started in search of seal . . ."

> "Saturday September 6th . . . 2 PM the boat that went in search of seal returned After examing all the islands near the mouth of the bay without Finding any seal on them but found men on all of them gathering Penguin eggs and feathers . . ."

This entry indicates that the Saldanha Bay seal colonies, which had been harvested previously (Thunberg 1793, p. 147), may already have been exterminated. The mention of people collecting penguin eggs and feathers is interesting, as it suggests that local, organized exploitation of the bird islands was taking place.

The *Antarctic* remained at anchor in Saldanha Bay until 11 September (Morrell states the 10th) taking on provisions and water. Before leaving the bay a dramatic incident occurred, which is not mentioned by Morrell.

> "Wednesday September 10th . . . 10 PM while the captain was Onshore James Sickles John Morhiser and George Soder attempted To take one of the whale boats and run away and Sickels said He would shoot the first man or officer that offered to stop him With two brassband pistols which were found in his possesion The next morning when the captain came onboard stowed Away in his mattrases they were loaded with a ball for when the Chief mate fired them off next morning he cut all his hand For they was loaded with such a heavy charge the captain when He came onboard asked them seperately if they intended to Leave the vessel and the said sickels told the captain that he Was and if not there he would the first chance this satisfied The captain that the man Sickels was dangerous man onboard The vessel he therefore sent for Mr. March who came onboard With 20 soldiers and after he had taken affadavits concerning The said sickels he was put in irons and sent to cape town as a Prisioner to be delivered to the counsel and to be dealt with him Accordingly . . ."

> "Thursday September 11th . . . 5 PM James Sickels went to cape Town in irons . . ."

At first sight it seems strange that Morrell did not mention this incident, but it is possible that he deliberately omitted any reference to it in his book,

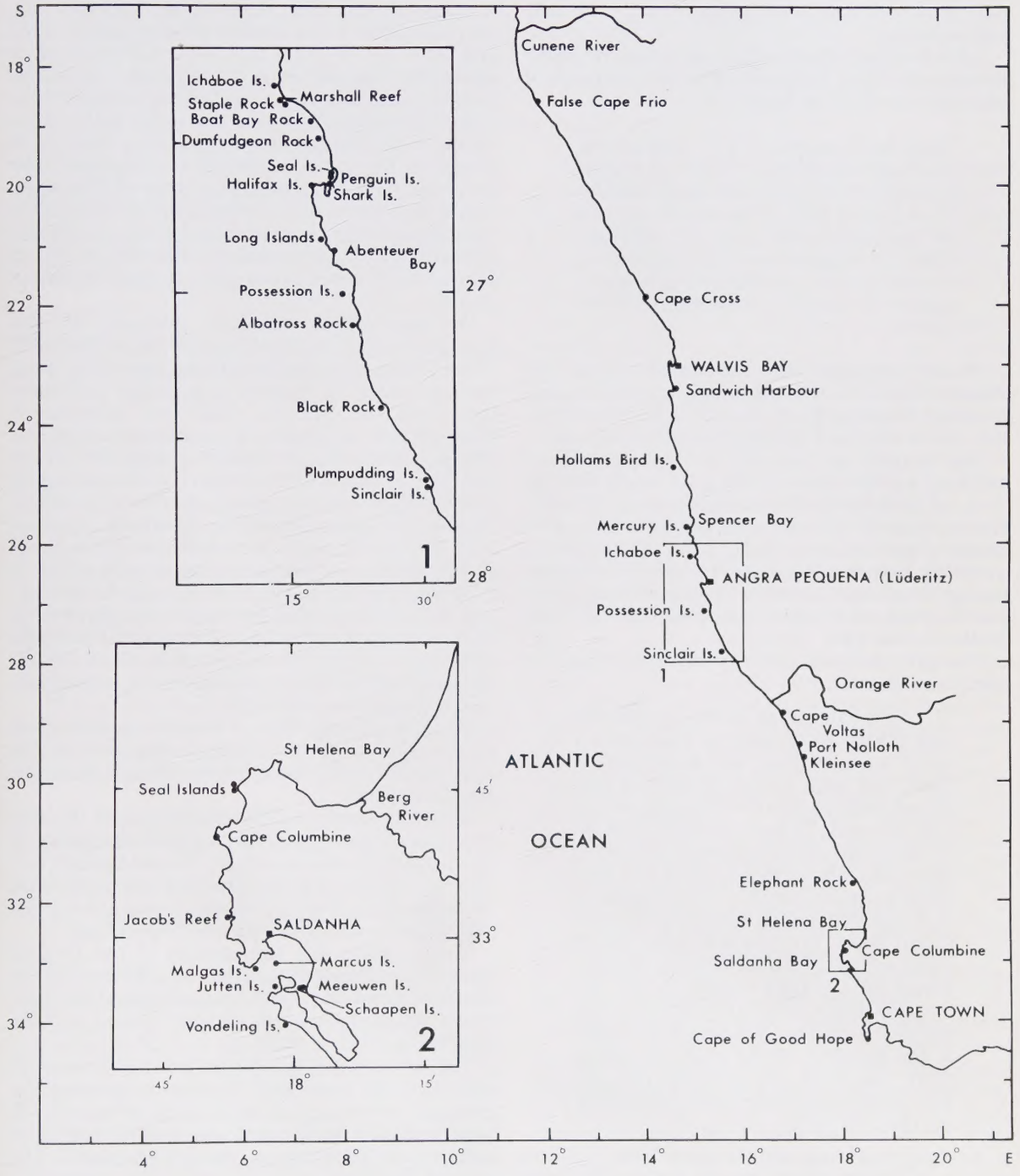

Fig. 1: Coast of southern Africa showing the localities mentioned

as an attempted desertion might have been personally embarrassing.

After leaving Saldanha Bay, the *Antarctic* sailed northwards along the coast. The first mention of seals occurs two days later.

> "Saturday September 13th . . . saw several seal in the water at 1/2 Past 9 AM abreast of Elephant river sent the boat with the 2d. officer To see if there was any seal or entrance to the river 12 meridian The boat returned saw a few seal but no entrance to the river Appearing to break across the mouth . . . Latitude 31°.40′ South"

Morrell mentions that they found a small seal island in 31°32′S, 17°56′E on 13 September, presumably Elephant Rock. Keeler does not refer to this island until 28 February the following year.

For the next six days the *Antarctic* continued working up the coast looking for seals. On the 16th, when the noon latitude was given as 29°10′S, Keeler reports that at 8 a.m. a boat was sent in search of seals but returned at noon without seeing anything. No mention is made of landing anywhere during this period, contrary to Morrell's statement that four hours were spent collecting wood at Cape Voltas on the 18th.

The entry for 20 September in Keeler's log is of particular interest.

> ". . . 1 PM came to an anchor on the east side of Possesion island in 4 fathoms of water went onshore and found where there had been About 50,000 per seal skins killed and about 10,000 lying rotten they appeared To have been taken about 20 years ago and to have been taken for there oil Only 5 PM got under way and stood to the northard . . . 7 AM came to in Angra Pequena in 4 fathoms of water found there the English cutter Lady Elizabeth of Liverpool Captain William Smith On a sealing voyage 12 months out and had 5 men drowned about the Middle of august 1828 found an island at the entrance of the Harbour where there had been about 50,000 per seal skins lying rotten Supposed to been killed for their oil only . . ."

Keeler's account of the seal mortality on Possession Island differs from Morrell's not only in the numbers involved (60 000 instead of "not less than half a million") but also in the suggested causes of the mortality. Morrell mentions that the carcases all had their skins on and suggests that they succumbed to a disease of some sort (p. 290) and, later (p. 312), that they were suffocated by a sandstorm. On the other hand Keeler obviously had the impression that most of the animals were killed. His use of the words "seal skins" rather than "seals" indicates that the animals may have been skinned. This is also implied by his suggestion that they may have been killed for their oil: the seals would have had to have been skinned before their blubber could have been removed. Keeler's estimate of the timing of the disaster also differs from that of Morrell's (20 years previously, compared with 5 years).

On the whole, Keeler's account of the phenomenon seems more plausible than Morrell's. The enormous number of animals reputed to have been involved by Morrell is equivalent to more than half the present total seal population (Shaughnessy, in press — a), and seems excessive. The possibility of some disease striking this colony (and one or two in Lüderitz Bay), while leaving an intermediate colony (Long Islands) apparently unaffected, seems unrealistic. Similarly, it seems unlikely that the seals were suffocated by a sandstorm. Sealers are known to have been active at Possession Island in the late eighteenth century, and in 1793 ten sealers are reported to have been marooned on the island for some time (Stackpole 1953, pp. 211-212). As suggested by Rand (1972), the likelihood of this mortality having been man-induced seems considerable.

Morrell believed that a similar mortality had occurred at two islands in Lüderitz Bay (presumably Seal and Penguin Islands), while Keeler mentions only one island.

A further point of difference between the two accounts at this stage of the voyage is the timing of the *Antarctic's* arrival at Angra Pequena (Lüderitz). Morrell claimed that the schooner only arrived on 24 September, whereas Keeler's journal implies that the schooner arrived on 20 September.

It is possible that the captain of the English sealer *Lady Elizabeth* was the same William Smith who discovered the South Shetland Islands in 1819: Smith was certainly still actively sealing in 1821 (Stackpole 1953, p. 364).

The entries in Keeler's journal for 21-24 September show that the crew was occupied in painting the ship and otherwise getting it ready for sea. On 25 September the boats were sent south in search of seals, while the *Antarctic* stood to the north. The journal continues:

> "Friday September 26th . . . saw a great Many fur seals in the water sent the

> boat inshore inshore [*sic*] Search of seal Latitude 25°.46′ South"
>
> "Saturday September 27th . . . 3 PM the boat returned saw a Rock which appeared to have about 300 seals on it . . . running along Shore in search of seal Latt 25°.15′ South".

This passage must refer to Mercury Island.

> "Sunday September 28th . . . running along shore in search of seal . . . lay by till morning waiting for daylight so that . . . we should not run past any seal . . . at 12 meridian run clost in with bird island which lies about 3 leagues From the main saw about 30,000 fur seals on it . . . Latt 24°.40′ South"

This clearly refers to Hollams Bird Island, which apparently bore a large population of fur seals at this time.

The *Antarctic* resumed its northward passage, still running along shore looking for seals, until 29 September, when it anchored in Walvis Bay.

According to Morrell's account, the schooner had remained in Angra Pequena all this time, and he only recorded it as leaving this anchorage on 2 October. Differences such as this in the timing and sequence of events between Morrell's and Keeler's accounts of the voyage occur frequently hereafter.

After going ashore for four hours, during which an interview with natives took place, Keeler records that the *Antarctic* got under way again at 11 a.m. on 30 September. Eight hours later, however:

> ". . . at 7 PM came too in shore in 10 fathoms of Water got ashore on the bar as we was a coming in there not being A regular chart of the bay . . . at 11 AM Got under way and stood to the southard Latt 22°.31′ South".

It is revealing that Morrell fails to make any mention of the *Antarctic* going aground on this voyage, presumably because of the unfavourable impression that this might have created.

For the next seven days, Keeler records the schooner as working to the south. On 4 October they were "still running along shore in search of seal" (24°34′S), and on 7 October "clost in with the land in Search of seal caught a small porpoise" (26°36′S). That afternoon the *Antarctic* came to anchor in Angra Pequena harbour.

At 8 a.m. the next day, the schooner got under way and stood for Ichaboe Island.

> ". . . at 1 PM sent the boat onshore at itchabow Island found the two boats there but had taken no seal As they had all gone in the water at 3 PM the 3 boats came Alongside hoisted them up and stood to the southard . . ."

This was presumably a rendezvous with the boats that the schooner had left behind when she left Angra Pequena on 25 September. This assumption is confirmed by Keeler remarking that once the *Antarctic* was at anchor in Angra Pequena on their return from Ichaboe, they ". . . began to take in The cutters empty water casks".

Keeler's statement that the boats at Ichaboe Island had taken no seal because ". . . they had all gone in the water" seems to imply that the island was a seal colony. This inference is later substantiated by entries for 24 November, 6 December *et seq.*, 19 December, and 26 January.

On 9 October, the *Antarctic* left Angra Pequena and stood to the south, bound for St Helena Bay for water, where they arrived ten days later.

Morrell's account for the period from 2 October (when he states the *Antarctic* left Angra Pequena) until 18 November is totally different from Keeler's. According to Morrell, after leaving Angra Pequena the schooner first visited a few rocks lying about a mile off shore and nearly half-way between Possession Island and Angra Pequena. These were presumably Long Islands. He asserts that the rocks were literally covered with fur seal and that a few were secured. The schooner is then stated to have left this anchorage and arrived at Ichaboe on 6 October. Here Morrell claims to have taken about 1 000 seals and made an excursion ". . . to a considerable distance . . ." into the interior of the country. On 20 October (the day after Keeler records the *Antarctic* as arriving in St Helena Bay), Morrell states that they weighed anchor at Ichaboe and steered to the north, arriving at Mercury Island on 22 October. Morrell's account implies that they remained there until 6 November. During this period he claims to have taken about 1 000 fur-seal skins from the island, and to have examined ". . . the interior of the country at a great distance inland . . .". After leaving Mercury Island, Morrell states that the *Antarctic* steered north for Bird Island (presumably Hollams Bird Island), where they arrived the following day. On 16 November the schooner is said to have left Bird Island and continued to the north, arriving at Sandwich Harbour on 18 November.

During most of the period from 20 October to 18 November when, as described above, Morrell claims to have been operating between Ichaboe Island

and Sandwich Harbour, Keeler records the *Antarctic* as being in the vicinity of St Helena and Saldanha Bays, 500-700 nautical miles to the south.

On arrival in St Helena Bay on 19 October, Keeler states that the *Antarctic* anchored on the west side of the bay where they went ashore and found fresh water.

> ". . . there is only one House in the bay and one englishman by the name of Thomson Ends calm all hands onshore cutting wood from the wreck Brittania cast away about two years ago loaded with copper"

For the next nine days the schooner remained in St Helena Bay while the crew cut wood and replenished the water. On 29 October, Keeler records that the *Antarctic* got under way and steered to the south close inshore in search of seals, arriving off Saldanha Bay at daylight on 30 October. A boat was sent ashore and returned at 11 a.m., but no seals were seen. This supports the belief that most seal colonies in the Bay were probably extinct by then. The schooner then returned to St Helena Bay where it remained at anchor till 11 November.

On 3 November the boats were sent to the south in search of seal. They stayed away for eight days but were apparently windbound and could not return earlier. As Keeler does not mention seals being taken, it would indicate that seals were rare in the vicinity of the present colony at Jacob's Reef and at Seal Islands near Cape Columbine where they occasionally occur.

On leaving St Helena Bay on 11 November, the *Antarctic* stood to the north. Her progress up the coast went as follows:

> ". . . November 12th . . . running Along shore in search of seal Latitude 32.03 South"
>
> ". . . November 13th . . . at 4 PM sent the boats clost in shore in search Of seal at 6 they returned but saw nothing . . . lay by till morning thinking it not prudent To run in the night at daylight filled away . . . running along shore Latitude 31°.08′ South"
>
> ". . . November 14th . . . running along shore in search of seal . . . Latt 28°.45′ East [*sic*]".

The position given here appears erroneous when compared with those for the preceding and subsequent days.

> ". . . November 15th . . . running along shore in search of seal . . . lay by till morning so not to Run apast any seal at daylight made sail . . . Latitude 28°.34′ South"
>
> ". . . November 16th . . . running along shore in search of seal . . . at 6 AM sent the boats in shore in search of seal at 11 AM The boats returned but saw nothing . . . 27°.41′ South"
>
> ". . . November 17th . . . at 1 PM sent the boats inshore in search of seal at 6 PM the boats returned with 86 prime fur seal skins hoisted them Up and stood off in the offning till daylight at daylight stood in And sent the boats ashore . . . Latt 27°.35′ "
>
> ". . . November 18th Commences with pleasant breezes from SW And fair weather at 1 PM the boats returned with 73 prime fur Seal skins hoisted them up and steered to the northard at 8 PM Came to an anchor on the east side of Possesion island . . . at 5 AM sent The boats to the leeward to ladys rocks in search of seal at 11 the Boats returned but did not disturb them as they had not all Hauled up . . ."
>
> ". . . November 19th Commences with fresh breezes from SW and fair weather at 1 PM sent the boats to Patterson Bay in search of seal . . ."
>
> ". . . November 20th . . . the boats still away"
>
> ". . . November 21st . . . at 4 PM the boats returned but found nothing . . . at 3 AM got under way and steered to the North at 12 meridian came to an anchor in Angra Pequena harbour In 4 fathoms of water found there the brig America Capt. Parker From New Bedford on a sealing voyage . . ."

This passage has been quoted at length because it represents a reasonably systematic search of the west coast between St Helena Bay and Angra Pequena, and it is interesting that no seals were encountered until 16 and 17 November, when the sealers appear to have visited either Plumpudding Island or Sinclair Island. The *Antarctic* therefore made two trips up the coast between St Helena

Bay and Angra Pequena, actively looking for seal colonies close inshore but only finding seals near Elephant Rock, in the vicinity of Sinclair Island or Plumpudding Island, and at "Ladys Rocks". This suggests that the large present-day colony at Kleinsee either did not exist at that time or was so small that it went undetected. Earlier travellers who also failed to report the presence of seals in this locality were Simon van der Stel's reconnoitring party in 1685 (Waterhouse 1932, p. 147) and Gordon and Paterson in 1779 (Forbes 1965, p. 85). The Kleinsee colony may therefore have become established comparatively recently. On the other hand, the crew of the *Antarctic* must have overlooked the small colony at Robbe Island, Port Nolloth, which was harvested till at least 1835 (Alexander 1839).

The identity of the "Ladys Rocks" colony is not known with certainty. If, as Keeler's journal indicates, the prevailing wind was from the south-west, and the boats were sent to leeward from the east side of Possession Island, then the colony must have been in the vicinity of what is currently known as Long Islands (see also notes on entry for 2 April). Neither do we know the identity of Patterson Bay.

The reference to the brig *America* is interesting, as the G. W. Blunt White Library also possesses a journal of the brig *America* (Capt. Avery Parker) of New Bedford, on a whaling and trading voyage to the South Atlantic, 1829/30 (log-book no. 557). Unfortunately, most of the pages of this journal have been subsequently used as a scrapbook and overlaid with newspaper cuttings, but the entry for 11 July 1830 mentions "Ichabo Island NE 10 miles . . .". Clearly, therefore, the *America* must have made at least two voyages to this coast.

Starbuck (1878, pp. 266-267) records the brig *America* (149 tons), Avery F. Parker, Captain, as leaving New Bedford on 21 July 1828 for the Atlantic, but no arrival date or results of the voyage are given.

As mentioned above, Morrell claims that the *Antarctic* reached Sandwich Harbour on 18 November (the same day that Keeler records the vessel as being at Possession Island). Morrell then claims that the schooner left Sandwich Harbour on 20 November, arriving "Walwich Bay" (Walvis Bay) on the 22nd. From there, "As the season was not yet sufficiently advanced for the seals to come up in their usual numbers on the islands and rocks to the south of our present position . . .", Morrell states that ". . . I determined to improve the interim by making a deep excursion into the interior of the country . . . . I proceeded from the head of the bay, in the direction of east-south-east, to the distance of nearly one hundred and fifty miles; . . ." (p. 300). Morrell then proceeds to describe the habits of the natives, the nature of the terrain, and claims to have discovered copper, lead and iron ores, as well as gold-dust. His excursion is supposed to have ended on 13 December, when he returned to Walvis Bay.

Keeler's account of this period is entirely different, however, and according to his journal the *Antarctic* was actively sealing throughout, and at no time did it call at Walvis Bay. It seems unlikely that Morrell ever made his reported excursion into the interior from Walvis Bay, at least on this particular voyage.

According to Keeler's journal, the *Antarctic* resumed sealing on 22 November: the boats started for the north from Angra Pequena at 3 a.m. and the schooner got under way at 11 a.m.

> ". . . November 23rd . . . At 11 AM the boats returned with two men that they found On the beach without provisions or water kept them onboard rather Than let them go onshore and perish shipt them not haveing time To run down to the brig America to deliver them up"

From this it is inferred that these men were part of the brig's crew. Morrell makes no mention of this incident in his account, which is strange considering that it was the sort of dramatic incident which he liked to include.

> "Monday November 24th . . . at 1 PM came to an anchor on the east side of Itchabow Island In 4 fathoms of water employed in landing the bread casks on the Island . . . at 5 AM the boats went in Search of seal at 12 meridian the boats returned with 71 prime skins"

This entry (and that for the 25th) suggests that Ichaboe Island was to be manned and used as a sealing base. It is not clear where the 71 skins were taken: Morrell states (p. 294) that the shores of Ichaboe ". . . are resorted to by multitudes of fur-seal; we took about one thousand of their skins in a few days." It is therefore possible that these 71 seals were killed at Ichaboe.

> "Tuesday November 25th . . . the boats employed in carrying things onshore got under way and Steered to the south for Steple Rock . . ."

During the next two days the boats made three trips to Steple (Staple) Rock, securing a total of 565 skins (Table I). After the boats had returned on 26 November, the schooner got under way and steered

Table I: Daily catches of fur seals from the schooner *Antarctic*, as recorded by Keeler

Date	Number of skins taken		Locality
	Prime	Black pups	
1828			
16/11	86	—	Plumpudding Rock or Sinclair Island
17/11	73	—	Plumpudding Rock or Sinclair Island
24/11	71	—	Ichaboe Island?
25/11	400	—	Staple Rock
26/11	57	—	Staple Rock
26/11	108	—	Staple Rock
29/11	121	—	Mercury Island
29/11	249	—	Mercury Island
30/11	464	—	Mercury Island
3/12	124	—	Mercury Island
3/12	35	—	Mercury Island
3/12	48	—	Mercury Island
4/12	158	—	Mercury Island
6/12	518	—	Ichaboe Island?
8/12	289	—	Ichaboe Island?
9/12	290	—	Ichaboe Island?
10/12	300	—	Ichaboe Island?
11/12	560	—	Ichaboe Island?
14/12	215	—	Ichaboe Island?
17/12	17	—	Albatross Rock?
19/12	18	—	Ichaboe Island
29/12	25	—	Plumpudding Rock
1829			
1/1	4	—	Eighty-four Rock (Boat Bay Rock)?
7/1	188	—	Hollams Bird Island
23/1	81	354	Mercury Island
2/2	270	—	Eighty-four Rock (Boat Bay Rock)?
3/2	170	—	North Rock (Dumfudgeon Rock?)
9/2	14	—	Mercury Island
13/2	248	142	South Rocks (Long Islands?)
19/2	43	—	(Lüderitz islets?)
21/2	43	—	Plumpudding Rock
28/2	17	53	Elephant Rock
14/3	20	—	Plumpudding Rock
17/3	56	—	Mercury Island
21/3	1 344	—	Hollams Bird Island
26/3	22	—	Staple Rock
26/5	25	—	Mercury Island
Total	6 771	549	

for Mercury Island. The *Antarctic* anchored there in the afternoon of 28 November, and remained for five days. The boats were sent to the island seven times, securing a total of 1 199 skins (Table I). The schooner got under way again on 4 December and steered for Ichaboe, anchoring there on the morning of 5 December.

On 6 December, Keeler records the vessel as "employed in landing salt on the Island". This seems to confirm that Ichaboe was being used as a sealing base. The *Antarctic* remained at Ichaboe for 10 days and the boats were sent out seven times, achieving a total of 2 172 skins on six of them (Table I). Once again it is not stated where these skins were taken, but it seems likely that they were from Ichaboe. At noon on 14 December, the schooner got under way and steered to the south for Possession Island, with all hands employed in salting skins. The *Antarctic* came to anchor at Possession the following afternoon.

According to Morrell, the *Antarctic* left Walvis Bay on 15 December and steered for Mercury Island, calling at Bird Island on the way where "a few fur-seal skins" were taken. The schooner is said to have anchored at Mercury Island on 22 December. At this stage, Keeler's and Morrell's accounts converge for the first time since late September.

While the *Antarctic* lay at Possession Island, Keeler records that at daylight on 17 December the boats were sent southward in search of seals, returning at 11 a.m. with 17 prime skins. There is no mention of the locality at which these seals were taken, but the short time the boats were away (probably five to six hours) suggests that it must have been close to Possession Island. The closest colony south of Possession at present is Albatross Rock, which lies about 7 nautical miles away. It is just possible that the boats could have made the trip there and back in five to six hours (the weather at noon on the 17th was recorded as ". . . light winds from SSW and fair . . ."). Alternatively, the seals might have been taken at the southern end of Possession Island itself, but this is considered less likely, as the time taken seems excessive for such a short distance and there was no other recorded attempt to take seals on Possession Island during this voyage.

On 18 December, the *Antarctic* sailed from Possession Island to Ichaboe Island, and the next day the boats were sent in search of seals, returning after three hours with 18 prime skins. It is assumed that these were taken at Ichaboe itself. That afternoon the schooner got under way again and steered north for Hollams Bird Island, anchoring there on 20 December. Keeler records the following:

> "saw no plenty Of seal but no place to land . . . . a very Heavy sea running"

and on the following day:

> "Monday December 22d . . . caught a

> great number of fish . . . at 9 AM the boats started with the intention of landing But the surf running so high rendered it impossible of landing returned Haveing made several attempts at 11 AM got under way and steered To the southard . . .".

Hollams Bird Island is the furthest seaward of the colonies of *Arctocephalus pusillus* (about 6 nautical miles off shore), and is the most difficult of all to land on owing to the wave action, which tends to break right round the island, and the lack of any beaches for landing (Morrell's claim that a few turtle may be found on a small sandy beach on the east side of the island is disputed: the east side of the island today is almost entirely composed of rugged, overhanging cliffs 3 — 6 m high). Keeler's account, in fact, is very reminiscent of the conditions that one encounters today when attempting to land on the island.

In the evening of 23 December the *Antarctic* anchored at Mercury Island. Keeler describes the events of the next day as follows:

> ". . . at 8 AM landed on the island after Seal after haveing knocked the seal and bringing them From the water edge when a heavy swell came in and washed 3 men off and one of them drowned by the name of Willaim Ogden belonging to New York but the other two was saved".

Keeler's account of this occurrence is essentially the same as that of Morrell, though considerably more succinct.

The *Antarctic* left Mercury Island the next day and steered south for Angra Pequena. In Morrell's published account, the next four months (until 19 April) are dismissed in one sentence — "We continued plying to the southward, taking advantage of the land-breezes by night and the sea-breezes by day, stretching along the coast, and carefully examining every rock and island on which fur-seals were likely to be found, for more than three months, when we found ourselves once more in the thirty-second degree of south latitude." (p. 307). Keeler's account suggests that this period was far more eventful than is implied by Morrell's rather bland statement, as will be shown below.

The day after the *Antarctic* left Mercury Island, Keeler records

> "Midnight fresh breezes with a heavy Sea running at 1 AM shipt a sea carried away the Starboard Boat & davits".

Instead of making for Angra Pequena directly, the *Antarctic* arrived off Plumpudding Island on the evening of 28 December and next morning sent the boats ashore, where 25 prime skins were taken. The schooner then filled away for Angra Pequena, arriving that evening.

> "at [time undecipherable] got Under way and steered for Steple rock at 1 AM Mr. West ran away from the Ladys Elizabeth and came Onboard the antarctic"

It will be remembered that the *Lady Elizabeth* was an English cutter from Liverpool that was sealing on the coast and had been out for a year when first encountered in Angra Pequena on 20 September.

> "Wednesday December 31st . . . at 6 PM came to an anchor clost in with 84 Rock Fell in with the Brig America Capt. Parker and mated With her "

The process of "mating" between two or more vessels was well known amongst whalermen, and has been described, for instance, by Scammon (1874). The boats from the mated vessels would, by prior arrangement, cooperate in the chase, and the oil from any whales killed would be shared equally between the vessels. Such an arrangement between sealers has previously been documented by Allyn (1879), but it is not clear from Keeler's account whether (during the period in which the two vessels were mated) proceeds of the hunt were divided equally between them and, if so, whether the numbers of seal skins referred to by Keeler in his journal were the total catches or only the *Antarctic's* share.

The *Antarctic* sent its boats away to look for seal at 3 a.m. on 1 January, and they returned at 1 p.m. with four prime skins. It is not clear where these skins were taken, but as the schooner was anchored close to Eighty-four (or Boat Bay) Rock, it is assumed they were taken from that colony.

As the weather became rough after the boats returned, both ships got under way, the *Antarctic* working to windward, losing sight of the *America* at 4 p.m. but arriving in Angra Pequena at 6 p.m. with the jib stay and bowsprit shrouds carried away. The next day was spent repairing the storm damage while at anchor. In the afternoon of 3 January, the

schooner got under way again and stood to the north, arriving on 5 January at Ichaboe, where the morning was spent rafting off water casks. The *Antarctic* then resumed its passage to the north, closing in with the land in search of seals. The next day the schooner fell in with the brig *America* again, and two hours later they anchored at Hollams Bird Island. The next morning they succeeded in landing and took 188 skins.

While at anchor at Hollams Bird, Keeler records that he "saw a great many humback whales". Morrell (p. 296) claimed that "A vast number of right whales . . ." frequented a reef associated with this island in July and August (and at Ichaboe Island in June — p. 293). Because he was not in fact on the coast at all at that time of year (at least on this voyage) his claim may not be based on direct observation. Keeler's record of humpback whales in this vicinity is interesting, as it would be expected that in January the greater part of the population of this species would be in much higher latitudes, feeding. However, the majority of nineteenth-century catches of humpback whales off Walvis Bay, as shown by Townsend (1935), occurred in October, November and January, so confirming Keeler's observations.

On 8 January, the two vessels got under way again and stood to the north.

> "Friday January 9th . . . running along shore with the Brig America in company 11 AM hauled up the Squaresail and waited for the brig to come up she not Being able to keep up with us with all her studing sails"

There is no further mention of the *America* until 30 January, and it is not clear whether the two vessels remained in company for the intervening period. It seems likely, however, that the inability of the brig to make the same speed as the schooner might have dissuaded the *Antarctic* from prolonging the mating.

At 6 p.m. on 9 January, the *Antarctic* anchored in Walvis Bay. The next morning (and the one following) parties went ashore and interviewed the natives, also purchasing some bullocks and sheep from them. On 11 January, the schooner resumed her passage northwards, keeping continuously along the shore in search of seals. At noon on 13 January, the vessel was in lattitude 21°59′S with ". . . light breezes & clear". At 6 p.m. that night they ". . . Came to an anchor clost in the shore so as not to run past Any seal in the night at daylight got under way Ends Pleasant Latitude 21°.13′ South".

This passage is extremely interesting. Cape Cross lies in latitude 21°47′S, and it seems that the crew of the *Antarctic* failed to see any seals ashore there. If the weather was fine and the vessel close enough inshore to anchor, it seems most improbable that they could have failed to have spotted the large seal colony that today extends from the headland south along the beach for about 2-3 km. Morrell (p. 316) also described Cape Cross and the anchorage there without mentioning seals. It is possible, therefore, that the colony either did not exist at that time or was very small. This is surprising, as Axelson (1973, p. 59) concluded that Diego Cão sighted seals at Cape Cross in 1483 because he apparently named the cape Cabo do Lobo. Because lobo in Portuguese can mean either seal or wolf, this could refer equally well to brown hyaena or black-backed jackal (which occur in the area now) as to seals. Thus, we are not convinced that the Cape Cross seal colony existed in 1483.

The first visitor to Cape Cross after Morrell of whom we are aware was Captain W. Messum, who spent many years on the coast of South West Africa in search of guano and other profitable products and who visited Cape Cross between 1846 and 1848 (Krynauw 1969). Despite landing in the area, his descriptions of Cape Cross make no mention of seals (Andersson 1861, p. 298; Krynauw *op.cit.*), which we consider significant in view of the commercial importance of such a discovery. The earliest reference to seals at Cape Cross appears to be in the log-book of the German cruiser *Möwe* (Captain Hoffman) which called at Cape Cross in October 1884. As well as reporting on the presence of hyaenas (see above), hares and snakes, Hoffman mentions that there was a large group of seals on the rocks at the Cape itself (Krynauw *op.cit.*). We therefore conclude that the seal colony established itself at Cape Cross sometime between 1848 and 1884, and that it is not a long established colony as previously thought (Rand 1972).

The *Antarctic* continued up the coast, but at 3 p.m. on 15 January tacked and stood to the south for Angra Pequena.

> ". . . thinking it not prudent to go any farther to the Northard as we had not seen any sines of seals since our leaveing Bird Island"

As no noon position was given for the 15th, it is not known how far north the *Antarctic* searched. However, from their rate of progress up the coast, it is unlikely that they went farther than 20°S, and so could not have seen the colony which now exists

at False Cape Frio (18°30′S).

The schooner called at Mercury Island on 23 January and took 81 prime skins and 354 black pups. This is particularly interesting, not only for its indication that sealing tended to be indiscriminate at that time, but also because the presence of black pups demonstrates unequivocally that Mercury Island was a breeding colony in 1829.

The *Antarctic* left Mercury Island the same day and continued to the south, reaching Ichaboe Island at daylight on 25 January, where the boats were sent ashore.

> "Monday January 26th . . . employed in dragging off the Carcases in the water at 6 PM the schooner came to an Anchor on the east side of Itchabow Island . . . . Employed in dragging off carcases From the top of the island in the water"

Although it is not stated, it is assumed that the carcases referred to were seal carcases, and this would confirm that Ichaboe was at this time a seal colony, and that the animals taken between 6 and 14 December the previous year were actually killed on this island. It is not clear why the carcases were being dumped, nor why they had been left on the island and not dumped on the day they were skinned, as is the modern practice. It is possible, however, that they were left there by a sealing party from one of the other vessels on the coast at the time that had called at the island after the *Antarctic's* previous visit. The crew of the schooner may have wished to remove the carcases in case they discouraged other seals from returning.

On the 26th, the *Antarctic* got under way again to the south, anchoring at Angra Pequena at 11 a.m. the next day. The schooner remained at anchor for three days while the crew stitched sails. On the 30th, the *Antarctic* hauled alongside the *America*, discharged spare provisions on board her and received water in exchange. Early next morning part of the brig's crew came on board the *Antarctic* which sailed to the north. Five hours later, they spotted the *Lady Elizabeth* near Ichaboe, and in the afternoon they closed with Mercury Island but, finding no seals there, they stood to the south again.

This inability to find any seals on Mercury Island in late January suggests either that the colony must have been small, or that it had been vacated owing to the disturbance caused by sealing eight days earlier.

On 1 February, the schooner anchored at Ichaboe, where a barrel of eggs was obtained. Next morning the *Antarctic* stood to the south for Eighty-four Rock.

> "Tuesday Febuary 3rd 1829 Commences with pleasant breezes From SW and fair weather at 2 PM sent the boats in search Of seal at 6 PM the boats returned with 270 prime fur seal Skins Midnight fresh breezes and clear at daylight sent The boats on North Rock in search of seal saw the Ladys Elizabeth about 20 miles to the windward of where we first Saw her at 10 AM the boats returned 170 fur seal skins"

It is assumed that the skins taken on 2 February (Civil Time) were from Eighty-four Rock. The identity of "North Rock" is unclear. Because the *Antarctic* was in the vicinity of Eighty-four Rock, it is likely to have been one of the other Lüderitz islets, all four of which currently support seal colonies. Keeler referred to another of them (Staple Rock) earlier. Thus, North Rock could be either Marshall Reef or Dumfudgeon Rock. Reference made to North Rock by the Angra Pequena and West Coast Claims Joint Commission (1885, p. xxxvi) indicates that the name did not refer to ". . . the two islands called the Eighty-fours . . .", Black Rock, ". . . Steeple (or Staple) Rock and Reef . . .", Hottentot Bay Island, Shark Island, Angra Rock, Shearwater Bay Rock or Boat Bay Rock. Evidence to the Commission by John Gove of Ichaboe (p. 53) indicates that Steeple Reef was also known as Marshall Rock. From this, we deduce that North Rock was Dumfudgeon Rock. However, there is one point of confusion in the above list of islands from the Joint Commission, because it includes both "Eighty-fours" and Boat Bay Rock which today are considered to be synonymous. The only other reference we have found to North Rock is on chart S.A. 56(T) published by the South African Hydrographic Office on 22 April 1965. A "North Rocks" is placed at 26°01,8′S, 14°57,6′E, approximately 16 nautical miles north of Ichaboe. However, this appears as a point on the mainland and seems most unlikely to have been a seal colony.

The schooner returned to Angra Pequena on 4 February and remained there four days while the crew repacked skins and painted the boats. On 8 February, the *Antarctic* got under way again and stood to the north for Mercury Island. Next morning the boats took 14 skins from the island, and Keeler records:

> "employed in digging for fresh water On the main but found none".

This contrasts with Morrell's account of Spencer Bay (in which Mercury Island lies). According to him (p. 295), there was a Hottentot village about 40 miles east-by-south from the head of the bay, with "... four refreshing springs between the village and the bay."

Next morning the *Antarctic* got under way to the south, coming to anchor finally inside South Rocks on 12 February. The next morning the boats landed and took 248 prime skins and 142 black pups, and at 9 a.m. the schooner got under way again and stood to the north for Ichaboe. She arrived there at 3 p.m., which, with the noon weather recorded as light winds from SSW, suggests that "South Rocks" must have been some considerable distance from Ichaboe Island. On the assumption that the schooner averaged a ground speed of 5 knots, the colony would be placed about 10 miles south of Angra Pequena, or near what is known now as Long Islands. The use of the plural "rocks" also suggests Long Islands, as these comprise three rocky islets separated from each other at high tide, together with a fourth islet 1 km south. The identification of "South Rocks" as Long Islands is supported by Morrell's statement that in early October he took some skins at a colony whose geographical position agrees closely with that of Long Islands (see previously).

Historically the name "Long Island" seems to have referred to what is now known as Shark Island in Lüderitz harbour. In a letter from Daniel De Pass to the Colonial Office dated 13 July 1883, the following passage occurs:

> "I have been concerned as a lessee in the Ichaboo group of guano and seal Islands, of which Long Island, Penguin Island, and Seal Islands are in the harbour of Angra Pequena, the former less than half a mile from the mainland . . ." (Anon. 1884, p. 9).

In a second letter from De Pass to the Colonial Office dated 26 June 1884, he states:

> "Do the Germans mean to lay claim to Angra Pequena harbour with our British islands, called on the map Shark Island (but in our lease Long Island) and Seal Island, on the north side of the bay?" (Anon. 1884, p. 51).

The *Antarctic* remained at anchor at Ichaboe for six days, apparently because of inclement weather. A boat was sent out for the first time on 18 February but returned unsuccessful, "... it being very rough". The next day, the schooner got under way for Angra Pequena at 5 a.m., but the boats were sent in search of seals at 6 a.m. and returned at 11 a.m. with 43 skins — presumably taken from one of the Lüderitz islets. The *Antarctic* finally reached Angra Pequena that night.

> "at 1 AM got under way and steered to the southard Leaveing the carpenters to build a new boat"

This was presumably a replacement for the boat lost on 26 December.

After calling at Plumpudding Island on 21 February, where 43 skins were taken, the schooner continued to the south, arriving at St Helena Bay on 1 March. During this leg of the voyage, Keeler records the ship as "Running along shore in search of seal" on only one day (25 February), when the noon position was 30°10′S. However, the day before reaching St Helena Bay, a landing was made on Elephant Rock, where 17 prime skins and 53 black pups were taken. This confirms the status of Elephant Rock as a breeding colony at that time.

The *Antarctic* remained at anchor in St Helena Bay for six days while the crew painted the ship, collected wood and replenished the water. On 7 March, the schooner got under way to the north again. Keeler records the vessel as running along shore in search of seals on 8 March only. The entry for the next day reads:

> "at 7 PM rounded to under The single reefed foresail till daylight so as not to run Past cape Voltas at daylight filled away and run In for the land . . . . Latt 29°.04′ South"

> "Wednesday March 11th . . . . at 8 AM came to an anchor In cape Voltas bay in 13 fathoms of water all hands Employed in cutting wood Latt 28°.42′ South".

It is assumed that the wood referred to was driftwood, as there is very little natural timber in this vicinity today. Morrell (p. 286) referred to the great quantity of wood on the beach which he assumed came down the Orange River.

At 1 p.m., the *Antarctic* got under way again and continued to the north, calling at Plumpudding Island on 14 March and taking 20 skins. That same evening she anchored at Angra Pequena.

> "found there the Brig Cloadio of Sag harbour Capt. Griffen on a sealing voyage at 4 AM Launched the new whale boat at 5 AM the boats Started for Itchabow Island"

Starbuck (1878, pp. 268-269) records the brig *Claudio* (136 tons), A. K. Griffin, Captain, as leaving Sag Harbor in October 1828 for Africa, returning 19 November 1829 with 300 barrels of whale oil and 300 "furs". Presumably the brig's voyage was not very successful, especially as the *Antarctic* off-loaded some skins onto the brig at the end of April.

At 7 p.m. the *Antarctic* got under way and stood to the north, reaching Ichaboe the following afternoon, only to find that the boats had taken no seals. The schooner resumed her northward passage and arrived at Mercury Island on the morning of 17 March, where 56 skins were taken. The same afternoon she left again for Hollams Bird Island, arriving there on 18 March. Because a very heavy sea was running, the schooner waited off the island until 21 March, when a landing was made and 1 344 skins taken. On the 22nd, the *Antarctic* got under way and stood to the south, closing in with Mercury Island *en route* but not landing. On 25 March, the *Antarctic* anchored at Ichaboe Island, and a party went ashore and collected eggs. The next morning, the schooner got under way again and a party was landed on Staple Rock, where 22 skins were taken. The vessel then proceeded to Angra Pequena where it remained for two days while skins were repacked. On 29 March, the *Antarctic* shifted its position to the lee of Shag Rock where it was prepared for sea. Salt was boated out from Cross Point (now known as Diaz Point) and also from the brig *Claudio*, and some seal skins were put on board the brig. (The schooner was presumably lying in Guano Bay in the lee of what is now called Halifax Island. We know of no other reference to Halifax Island as Shag Rock.) Finally, at 11 a.m. on 2 April, the *Antarctic* got under way to the south.

Six hours later the schooner closed with "Ladys Rock". The wind at noon was recorded as ". . . moderate breezes from SSW . . .". Because it took six hours for the boats to make the round trip from Possession Island to Ladys Rock(s) on 18 November (when the noon weather was ". . . fresh breezes from SW . . ."), we suggest that this colony may have been situated between Possession Island and Long Islands. The only islands in this vicinity are three small ones at 26°47′S, 15°09′E in the bay known variously as Bain's Bay and Abenteuer Bay. They were visited in January 1979, when no seals were present. The smaller islands could not have supported seals as they are bare and must be awash in heavy weather. On the other hand, the largest one could have supported a seal colony previously, as cormorants nest there now and much of its surface is covered with guano. Consequently, we conclude that these islands in Abenteuer Bay were known to Keeler as Ladys Rock or Rocks.

The rest of the voyage south was uneventful until the morning of 12 April when the North Cape (North Head) of Saldanha Bay was seen.

> "at 2 PM sent the boat ashore to see if there was any seal To be got at 9 PM got inside of the capes and came to At 10 the boat returned but could not get any"

The next day was spent in the bay replenishing water and painting the boats.

> "Wednesday April 15th . . . at 2 PM got under way and stood To the Northard saw the Brig Columbine ashore on the North point of St Helana bay and had been ashore 14 Days and all the crew saved and was from England Bound to Van diemans land Capt. Stewart and had A very valuable cargo onboard at 11 PM came to an Anchor in St Helana bay . . ."

Possibly, this wreck gave Cape Columbine, just to the south, its name.

The *Antarctic* remained in St Helena Bay for three days, while the crew cut wood. On 18 April, the schooner left for the "Cape of Good Hope" (presumably Cape Town).

> "at 3 PM sent the boat into the wrack and brought off Lieutanant Mitchel with his baggage to carry to cape town"

According to Morrell (p. 307), Lt Mitchell of the Royal Navy was a passenger on the *Columbine*. It is not clear why Morrell chose to assist him, but it seems likely from Morrell's account that he wished to use Lt Mitchell's services to obtain salvage rights to the brig and its cargo.

The *Antarctic* anchored in Table Bay on 21 April, where part of the crew went ashore on liberty.

> "Thursday April 23rd . . . at 10 AM an English man of war came to an anchor in the bay which is the One that has

> been looking after the schooner she haveing been Reported as pirate by the man the captain put ashore at Saldanha bay for mutionus conduct as soon as the govener Found out this he sent immediately and had the man taken Up and put in prison at 11 AM she fired a salute of 21 guns it Being the king of england birth day"

The man referred to was clearly James Sickles (or Sickels) who attempted to desert the *Antarctic* on 9 September. This incident is not referred to at all by Morrell, presumably because the whole affair of the attempted desertion was embarrassing to him.

The next morning the *Antarctic* got under way again and stood to the north. The voyage was uneventful (apart from the "square sail boom" being carried away on 26 April) until they neared Possession Island, where, on 28 April, Keeler reports that they saw several seals in the water. The next day the *Antarctic* anchored in Angra Pequena.

> ". . . found that the brig America had gone to the cape After cables and anchors"

Morrell claimed that the schooner sealed on the way up from Cape Town on this leg of the voyage, but Keeler makes no mention of this.

The day following arrival in Angra Pequena the crew repaired sails and repacked skins. On 1 May the schooner got under way again for the north. After running along the shore in search of seals the following day, Keeler records:

> "Sunday May 3d . . . at 4 PM spoke the schooner Spritely from Desolation bound To London with 114 tons of Elaphant Oil and about 1000 fur seal Skins at 10 PM came to an anchor on the NE part of Bird Island In 10 fathoms of water at 8 AM sent the boat into the islan But there not being seal enaeogh up returned at 11 AM Got under way and began plying to the windward".

As the *Spritely* was presumably on passage from Desolation (now known as Kerguelen) Island, the fur-seal skins on board were probably taken there rather than on the African coast.

The lack of seals on Hollams Bird Island is surprising considering the report of 18 September the previous year that there were an estimated 30 000 seals on the island. Presumably either the original estimate was too high or the island had been extensively sealed in the interim.

The *Antarctic* reached Angra Pequena again on 6 May and anchored there until 17 May. During this period, the crew overhauled the rigging and repacked skins. On 10 May, the boats were sent to the north in search of seals, returning on 15 May, but they found none.

> "Sunday May 17th . . . at 3 PM lowered all the boats and went And fastened to a humback whale . . . . at 6 AM got under way and stood To the southard with the Cloadio in company for Plum Pudding rock"

It is likely that the attempt to catch a whale (apparently unsuccessful) occurred mostly as a diversion at the end of a prolonged period of inactivity (the last successful day's sealing being 51 days previously).

That afternoon the *Claudio* was lost sight of, and at 11 the next morning Plumpudding Island was seen, but because of fog it was not possible to see whether any seals were ashore. At 10 the following morning (20 May), the fog lifted and Keeler recorded that very few seals were up, so the *Antarctic* returned to Angra Pequena. On the way, the *Claudio* was seen at anchor in the lee of Possession, and the brig arrived the following morning in Angra Pequena.

It seems as though the *Antarctic* was preparing to stop sealing and leave for home, for on 21 May Keeler recorded:

> "at 3 PM got 19 bullock and 19 sheep from the hottentots".

At 6 the next morning the *Antarctic* got under way and stood to the north with the *Claudio* and the *America* in company. However, because of fresh breezes from the north, the *Claudio* and the *America* turned back for Angra Pequena at 11 a.m. and the *Antarctic* an hour later. The schooner finally left the bay on 24 May, leaving a "small boat" with Capt. Griffin of the *Claudio* and taking his sail boat in exchange. Two days later the schooner briefly anchored at Mercury Island and in two hours took 25 skins. At 11 a.m. the next day (27th), ". . . saw Bird island but no seal up bore away for benguela."

This concluded the sealing phase of the *Antarctic's* voyage. The schooner reached Benguela in Angola on 1 June and New York on 14 July.

Morrell (pp. 316-320) claimed that the schooner

finally left Angra Pequena on 3 May, passing Cape Cross on 8th and Cape Frio on 13th and anchoring at Great Fish Bay (Baia dos Tigros) on 17 May, where the vessel is supposed to have remained until 27 May. During the latter period, Morrell claims that they were absent from the vessel for a week and penetrated many leagues into the interior. The *Antarctic* is then supposed to have sailed to Port Alexander (it is not clear whether the vessel called there or not) and finally reached Benguela on 4 June. From Cape Cross to Benguela, Morrell claims that the schooner kept close inshore examining the coast: as we have seen, Keeler makes no mention of the *Antarctic* anchoring at any spot on the coast between Hollams Bird Island and Benguela. Furthermore, Keeler only records seeing land twice before reaching Benguela:

> "Friday May 29th . . . . At 4 saw the land bore away and set the squaresail . . . . Latitude 18°.40′ South"

> "Monday June 1st . . . . at 9 AM Saw St Philip bonnet Latitude 12°.48′ South".

Morrell's arrival date in New York at the end of the voyage (14 July) is, however, in agreement with that of Keeler.

DISCUSSION

Morrell's veracity

From the comparison of Keeler's journal with Morrell's published account, there are obviously major differences between the two descriptions of this particular section of the voyage. These principally take the form of differences in the timing of events, omissions of apparently significant occurrences by Morrell, and elaboration, exaggeration or fictionization of events by Morrell.

Several examples of differences in the chronological sequence of events between the two accounts have already been indicated. Apart from the first few days after the initial landfall at Saldanha Bay, two or three days around 24 December (when Ogden was drowned), and the period 19-30 April (when the *Antarctic* was at Cape Town and travelled up the west coast to Angra Pequena), the two versions of the voyage hardly ever place the vessel in the same place at the same time. The impression created is that Morrell's account is based on a recollection of what happened, and that he did not have access to (or ignored) the ship's log-book or any other written record of the cruise. Several times Morrell describes an event which Keeler also mentions, but at quite a different time in the voyage: for instance calling at Elephant Rock (13 September cf. 28 February) or at Cape Voltas (18 September cf. 11 March). It is chronological inconsistencies such as these that might account for the exceptionally fast sailing times inferred from Morrell's versions of some of his other voyages (Bertrand 1971, p. 133).

Some of the more important events that were omitted from Morrell's account of this voyage but mentioned by Keeler have been indicated already, for instance the attempted desertion at Saldanha Bay on 9 September and the vessel running aground near Walvis Bay on 30 September. We suspect that these events were deliberately omitted by Morrell as they might have reflected adversely on his authority or competence. Morrell also failed to mention any other vessels sealing on the coast at that time, whereas Keeler mentions three, the *America*, the *Claudio* and the *Lady Elizabeth*, as well as the *Spritely*, which appeared to have been on passage rather than actually sealing. It is not clear why Morrell omitted them: data given by Starbuck (1878) for the first two vessels indicate that they could have been on the African coast at that time, thereby providing support for Keeler's account.

Morrell's elaboration or fictionization of events is typified by the descriptions of his purported excursions into the interior. If Keeler's account of the schooner's movements is correct, Morrell would not have had time to make these trips. Secondly, it seems most unlikely that the captain would have left his vessel in charge of a subordinate officer for such long periods. Furthermore, the validity of at least one of the excursions has been seriously questioned. From his own experience, Galton (in Hamilton 1870) concluded that Morrell ". . . evidently knew nothing about that part of the interior", because his description was quite contrary to reality. According to Keeler, several interviews were held with the natives on the coast, and it is possible that Morrell obtained most of his information on local conditions on these occasions.

In judging whether Keeler's or Morrell's account is more plausible, it should be remembered that they were apparently written with different ends in mind, Morrell's obviously being intended as a public presentation but Keeler's rather as a private journal. Consequently, one would expect the latter to be a more straightforward presentation of facts than

the former, as Keeler would seem to have no particular motive for wishing to impress a reader.

Nevertheless, despite the apparent flaws in Morrell's version of the voyage, his account cannot be dismissed as entirely fictitious. The *Antarctic* was present in the area concerned, even if it did not follow the timetable outlined by Morrell. The main objective of the voyage was sealing, and in this Morrell is reasonably consistent with Keeler concerning the islands visited and the number of seals taken. It is in Morrell's descriptions of what he might have considered the secondary objective of the voyage, namely, exploratory trips into the interior, that the worst lapses of credibility occur, though there is also an apparent trend for exaggeration throughout the account. Morrell gives the overall impression of being a romantic with an overwhelming urge for exploration and the public acclaim that this might bring him. It is in this light that his version of events should be regarded, and neither as a strictly reliable account nor as a work of complete fiction.

Bertrand (1971, p. 141) tried to ascertain in what light Morrell was held by his contemporaries. The most severe criticism was that contained in a letter written by Jeremiah N. Reynolds in 1834, in which (amongst many caustic remarks made about several people) he states that "Morrell who always sees through a glass dimly has described south sea penguin rookeries — but his descriptions have more poetry than truth". As Bertrand points out, however, this did not stop Reynolds from including discoveries by Morrell in his own report on islands, reefs and shoals in the Pacific Ocean, which was published as a House Document of the U.S. Congress in 1836. Bertrand also mentions two reviews of Morrell's book (both dated 1833), neither of which was unfavourable.

In this connection, it is interesting to quote remarks made by another contemporary of Morrell's, one who must have known him well. In September 1977, an unpublished autobiography of William Skiddy entitled "The ups and downs of sea life" was found in the G. W. Blunt White Library at Mystic. William Skiddy was part-owner of the *Antarctic*. The autobiography is a manuscript bound in two volumes (Miscellaneous Volume nos. 157 and 158) and, although it is undated, the last entry is for 1 June 1847. In the first volume the following passage occurs, quoted here in full because of its considerable interest.

> "I must here relate an expedition in which I was conserned. The Hero of this tale had been my mate in the ship Henri V for more than a year. he always appeared steady and active, although his mind was constantly bent on sealing voyages When the Francois 1st. was built in 1829, Mess C. Bergh & Co. as well as myself, wishing to serve him, and thinking that he would prove himself worthy our friendship we determined on building him a vessel. The Schooner "Antarctic" of 170 tons was completed and fitted out entirely under his own directions. She sailed well maned and cost us at sea $20,000. He was out one year and returned unsuccessful. Mr. Bergh asked my opinion, I told him it was hard to abandon a man because he had been unfortunate and if he had no objection we would let him try again. We therefore authorised him to fit her for another voyage, and this time for the South Shetlands. She had 27 men, 6 guns and provisions for three years. The Captain wished permission to take his wife, which I objected to, considering it a voyage quite unfit for a female. We however gave him a small interest in the vessel for which we took his note, $2,000 (never paid). This was no other than the Capt. R. Morrell — famous for having had his voyages written and published by Woodworth, famous for stealing his wife away in the vessel, stowed in the bread locker, famous for going altogether on a different voyage, the result of which proved him unworthy of trust and devoid of every principle of honour and honesty His Book would prove him a great Hypocrite did the contents originate from his own mind, but they did not, for Captain Morrell is quite inadequate to the task. I loaned him 20 volume of Capts Cook & Vancouver's voyages round the world (which he never returned) with views and descriptions of all they had seen in the Pacific ocean. this assisted Captain Morrell very much. After all his Bucaneering among the Islands, he took a freight from Mannilla for Cadiz, on his passage he stoped at several places, bartered part of the cargo for which he never gave any account, on arriving at Cadiz because they ordered him in quarantine, he made sail & arrived at Bordeaux. The cargo was received, and we were condemned to lose the

> freight, pay damages, and also for the cargo sold on the passage. The interest we gave him in the vessel according to law constituted him a partner, & he became liabel for all his acts, he had taken up at Mannilla $12,000 with heavy interest for years. At Bordeaux he took up $4,000 and came home. As the history of his voyage is published, although greatly exaggerated I shall say no more on the subject. only that he returned without having any accounts of the voyage and my share of the loss amounted to $10,000."

While Skiddy might seem to have had good reason for taking a rather bitter view of Morrell, given the financial losses that the latter's exploits cost him, his comments are of considerable significance. It is obvious that Skiddy considered Morrell's account of the fourth voyage to be partly fictitious, and the source of many of his statements to have been the voyages of Captains Cook and Vancouver. A detailed comparison of Keeler's account of the voyage with Morrell's would throw further light on Morrell's veracity.

Status of fur seals

If Keeler's account of the voyage is accepted, one can conclude that the following fur-seal colonies existed on the south-west coast of Africa in 1828/29: Elephant Rock, Plumpudding Island, Ladys Rocks, South Rocks (Long Islands?), North (Dumfudgeon?) Rock, Staple Rock, Ichaboe Island, Mercury Island and Hollams Bird Island. Three of these (from the occurrence of black pups) were definite breeding colonies: Elephant Rock, South Rocks and Mercury Island. It is also probable that seals occurred on Albatross Rock and Eighty-four (or Boat Bay) Rock. From the negative evidence in the journal, it seems that seals were rare or non-existent at the following localities where they occurred in the past or where they currently occur: islands in the vicinity of Saldanha Bay, Jacob's Reef, Seal Islands (near Cape Columbine), Kleinsee, Sinclair Island, and Cape Cross. The evidence regarding the Saldanha Bay islands, Jacob's Reef, Seal Islands, Kleinsee and Cape Cross has already been given. The lack of seals at Sinclair Island has been deduced from the fact that Keeler mentioned Plumpudding Rock five times but never Sinclair Island (or Roastbeef Island as it was probably known then — e.g. Rand 1949), only 2,8 km to the south. It is conceivable that "Plum Pudding Rock" was confused with Sinclair Island, but this is considered unlikely because of the use of the term rock rather than island (Sinclair Island having a surface area of 8 acres compared to 1,9 acres for Plumpudding Island — Rand 1963), and because of the small catches made there (maximum 86).

It is also of interest that, although the *Antarctic* made the voyage between Possession Island and Ichaboe or Angra Pequena four times and apparently sealed at Long Islands (South Rocks) once, no mention was made of seals occurring on the mainland near Wolf and Atlas Bays (opposite Long Islands) where large colonies exist now. Although it is not stated that a systematic search was made of the coastline between Possession Island and Angra Pequena, seal colonies on the mainland would have been advertised by a higher density of seals in the adjacent waters. This presumably would have prompted Morrell to send a boat ashore as he did on 13 September. Thus, the existence of colonies near these two bays cannot be completely discounted, but it seems unlikely.

Morrell (p. 289) also mentioned two small islands carrying seals in Whale Bay (27°23'S), agreeing in description and location with the present seal colony at Black Rock in Van Reenen Bay. Keeler, however, failed to mention this colony. As there is some doubt from Morrell's account whether he actually sealed there, it is possible that Keeler omitted reference to this colony because no attempt was made to exploit it. The name "Whale Bay" is used for Van Reenen Bay on Admiralty Chart 632.

Besides providing information on the existence of seal colonies, Keeler's account is invaluable for the insight it provides into contemporary sealing practice. Although it is not clear what class of seal was referred to by the term "prime skins", reference to black pups indicates that sealing at that time was not confined to a single age class. From the timing of the kills, it is also apparent that most of the sealing was concurrent with the breeding season (which occurs from late November to late December). Because at least four vessels were operating simultaneously in the 1828/29 season, it is clear that the disturbance to the colonies could have been considerable. This is supported to some extent by Keeler's comments on his last visits to Plumpudding Rock ("very Few seal up") and Hollams Bird Island ("not being seal enaeogh up" — 3 May; "no seal up" — 27 May), and the fact that only 25 skins were taken in two hours on the last visit to Mercury Island (26 May). It is possible that the sealers were actually taking adult cows, because these animals (and their black pups) are the dominant

class at the colonies from late November to early January. Juvenile animals apart from pups are rarely seen in the colonies during the breeding season, and adult bulls might have formed too formidable a target for clubbing. Consequently, the apparent depletion of the colonies may have been caused by both indiscriminate sealing and disturbance.

The serious effect that such operations could have had on a colony was illustrated when Captain Allyn arrived off Ichaboe Island in January 1830 (just over a year after Morrell's last successful landing there). All he found on the island was about 1 000 skinned carcases (Allyn 1879). Thus it seems that the colony must have been close to eradication by that time. Captain Allyn made subsequent voyages to this coast in 1834 (when he only secured 800 skins) and on two later occasions, with little success, and these may have been the last sealing operations on the west African coast for many years (Watson 1930).

In conclusion, the impression gained from both accounts of the *Antarctic's* voyage is that the abundance of fur seals on the west coast of southern Africa must have been very much less then than it is today, despite the existence of at least four island colonies that are now extinct (Plumpudding, Ladys Rocks, Ichaboe and Mercury). Counts of pups on aerial photographs of all the island colonies north of Cape Town in December 1976 totalled 37 800 (Shaughnessy, in press — b), from which the total island-based population can be estimated as at least 4 × 37 800 or 151 200 seals (this figure makes no allowance for pups hidden from view on the aerial photographs). The *Antarctic's* take of 7 320 animals in nine months in the same area does not, therefore, seem substantial by modern-day standards. Furthermore, both accounts of the voyage failed to mention the existence of any of the large fur-seal herds that now occur on the mainland. These comprise the major part of the present West Coast seal population. Counts of pups from aerial photographs of mainland colonies at Kleinsee, Atlas Bay, Wolf Bay and Cape Cross in December 1976 totalled 115 626 (Shaughnessy, in press — b), giving a total population of at least 462 500 animals, or about three times the island herds.

As several West Coast seal colonies had been exterminated prior to the *Antarctic's* voyage (e.g. Robben Island, Dassen Island, the Saldanha Bay islands, Possession Island, Seal and possibly Penguin Islands in Lüderitz Bay) and some were eradicated afterwards (e.g. Ichaboe Island, Mercury Island and possibly Plumpudding Island), the uncontrolled sealing of the seventeenth, eighteenth and nineteenth centuries must have reduced the fur-seal population on the West Coast substantially below its original abundance.

It was only, in fact, when the necessity for restricting sealing activity to certain seasons was recognized (Cape of Good Hope 1907), that the population of the Cape fur seal was able to recover in numbers to the level existing today.

The evidence provided by the *Antarctic's* voyage throws doubt on the presence in historical times of large mainland herds of fur seals on the West Coast. If they did not exist then, their present large size may represent the re-establishment in new localities of some of the extinct island populations. This could have arisen from two factors: firstly, increased disturbance at the original sites (Robben, Dassen, Possession, Penguin, Ichaboe, Mercury and some of the Saldanha Bay islands are or have all been subjected to subsequent permanent or semi-permanent human settlement); secondly, reduced predation or disturbance on the mainland (three of the four large mainland colonies are in proclaimed Diamond Areas to which human access is now strictly limited). Further research might provide more evidence of the historical distribution and abundance of Cape fur seals, information which is important in assessing the present relative status of the population and in deciding on suitable management action.

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LITERATURE CITED

ALEXANDER, J. E. 1839 — *An Expedition of Discovery into the Interior of Africa.* London; Colburn; 2 vols.

ALLYN, G. L. 1879 — *The Old Sailor's Story, or, A short account of the life, adventures and voyages of Capt. Gurdon L. Allyn, Including three Trips Around the World.* Norwich, Connecticut; G. Wilcox; 111 pp.

ANDERSSON, C. J. 1861 — *The Okavango River: a Narrative of Travel, Exploration and Adventure.* London; Hurst and Blackett; 371 pp.

ANGRA PEQUENA AND WEST COAST CLAIMS JOINT

COMMISSION 1885 — *Proceedings of the Angra Pequena and West Coast Claims Joint Commission, March-September, 1885.* Cape Town; Saul Solomon and Co.: 118 pp. + 48 pp. of minutes and 45 pp. of appendices.

ANONYMOUS 1884 — Correspondence respecting the settlement at Angra Pequena, on the S.W. coast of Africa. *Imperial Blue-Book* **C.-4190**. London; Eyre and Spottiswoode: X + 60 pp.

AXELSON, E. 1973 — *Congo to Cape: Early Portuguese Explorers.* London; Farber and Farber: 224 pp.

BERTRAND, K. J. 1971 — Americans in Antarctica 1775-1948. *American Geographical Society Spec. Pub.* **39**. New York; American Geographical Society: 544 pp.

CAPE OF GOOD HOPE, DEPT. OF AGRICULTURE 1907 — Guano Islands Commission's report, with evidence. In *Annexures to the Votes and Proceedings of the House of Assembly, Cape of Good Hope* **114 of 1907**:7 + 265 pp.

EDEN, T. E. Jr. 1846 — *The Search for Nitre and the True Nature of Guano, Being an Account of a Voyage to the South-west Coast of Africa*; etc. London; R. Groombridge and Sons: 133 pp.

FORBES, V. S. 1965 — *Pioneer Travellers of South Africa.* Cape Town; A. A. Balkema: 177 pp.

HAMILTON, R. V. 1870 — On Morrell's Antarctic voyage in the year 1823, with remarks on the advantages steam will confer on future Antarctic explorers. *Proc. R. Geogrl Soc.* **14**:145-156.

HART, S. 1957 — De eerste Nederlandse tochten ter walvisvaart. *Jaarboek van het Genootschap Amstelodamum, Amsterdam* **49:**27-64.

KRYNAUW, D. W. 1969 — Kaap Kruis. *Publikasies van die Historiese Monumentekommissie van Suidwes-Afrika* **4**:60 pp.

MORRELL, B., Jr. 1832 — *A Narrative of Four Voyages, to the South Sea, North and South Pacific Ocean, Chinese Sea, Ethiopic and Southern Atlantic Ocean, Indian and Antarctic Ocean*, etc. New York; J. and J. Harper: 492 pp.

MORRELL, B. 1844a — The coast of Africa from the Cape Colony to Ichaboe Island. *Naut. Mag.* **1844**:366-374, 418-423.

MORRELL, B. 1844b — *Morrell's Narrative of a Voyage to the South and West Coast of Africa: Containing the Information from Whence Originated the Present Trade in Guano, Found on Certain Islands on the Coast. With a Preforatory Advertisement by Lieut. Petrie, R. N.* London; Whittaker and Co: 144 pp.

RAND, R. W. 1949 — Notes on birds observed on Sinclairs Island (South West Africa). *Ostrich* **20**:130-136.

RAND, R. W. 1963 — The biology of guano-producing seabirds. 5. Composition of colonies on the South West African islands. *Investl Rep. Div. Sea Fish. S. Afr.* **46**:26 pp.

RAND, R. W. 1972 — The Cape fur-seal *Arctocephalus pusillus.* 4. Estimates of population size. *Investl Rep. Div. Sea Fish. S. Afr.* **89**:28 pp.

SCAMMON, C. M. 1874 — *The Marine Mammals of the Northwestern Coast of North America, described and illustrated. Together with an account of the American Whale-fishery.* San Francisco; J. H. Carmany: 319 pp.

SHAUGHNESSY, P. D. — The status of seals in South Africa and South West Africa. In *Mammals in the Seas. FAO Fisheries Series 5* vol. **3** (in press — a).

SHAUGHNESSY, P. D. — Population size of the Cape fur seal *Arctocephalus pusillus.* I. By aerial photography. *Investl Rep. Sea Fish. Brch S. Afr.* (in press — b).

STACKPOLE, E. A. 1953 — *The Sea-hunters.* Philadelphia; J. B. Lippincott Company: 510 pp.

STARBUCK, A. 1878 — History of the American whale fishery from its earliest inception to the year 1876. In *Rep. U.S. Commnr Fish. 1875-1876* **4**:1-779.

THUNBERG, C.P. [1793] — *Travels in Europe, Africa and Asia Performed Between the Years 1770 and 1779. Vol. 1 — Containing the voyage to the Southern parts of Europe and to the Cape of Good Hope in Africa in the years 1770, 1771, 1772, 1773.* London; W. Richardson and J. Egerton: XII + 317 pp. + XV.

TOWNSEND, C. H. 1935 — The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica, N.Y.* **19**(1):1-50.

WATERHOUSE, G. (Ed.) 1932 — *Simon van der Stel's Journal of his Expedition to Namaqualand, 1685-6.* London; Longmans, Green and Co.: 182 pp.

WATSON, A. C. 1930 — The guano islands of southwestern Africa. *Geogrl Rev.* **20**(4):631-641.

Fish. Bull. S. Afr. 12:20—25
20 *1979*

INCIDENTAL MORTALITY OF CAPE FUR SEALS DURING TRAWL FISHING ACTIVITIES IN SOUTH AFRICAN WATERS

P. D. SHAUGHNESSY and A. I. L. PAYNE

In order to estimate the number of Cape fur seals killed incidental to trawling activity, observations were made on both the mortality and the entrapment of seals on commercial and research craft. The number of seals attending the trawl net was also noted and, as expected, was greater on the West than the South Coast. Observations on mortality and entrapment were therefore treated separately for each coast. On the West Coast, both entrapment rate and mortality rate were found to be independent of the type of craft (commercial or research) and data were combined. However, on the South Coast a significant difference between research observations and commercial observations resulted in the discarding of research data for mortality calculations. An annual mortality of 4 210 Cape fur seals during bottom trawling by South African vessels south of the Orange River was estimated.

Om die aantal Kaapse pelsrobbe wat toevallig tydens bodemtreilbedrywighede gedood word, te skat, is waarnemings van beide die sterfte en verstrikking van robbe vanaf handels- en navorsingsvaartuie uitgevoer. Die aantal robbe wat by die treilnet aanwesig is, is ook genoteer en, soos verwag was, was daar meer aan die Wes- as aan die Suidkus. Die waarnemings oor sterfte en verstrikking is dus vir elke kus apart behandel. Aan die Kaapse weskus was die verstrikkings- en sterftekoerse albei onafhanklik van die soort vaartuig (handels- of navorsings-) en die gegewens kon saamgevoeg word. Aan die Suidkus het die beduidende verskil tussen navorsings- en handelswaarnemings daartoe gelei dat die navorsingsgegewens vir die sterfteberekenings buite rekening gelaat moes word. Na beraming word 4 210 Kaapse pelsrobbe jaarliks in bodemtreilnette deur Suid-Afrikaanse vaartuie suid van die Oranjerivier gedood.

The Cape fur seal *Arctocephalus pusillus* is abundant in the coastal waters of southern Africa. Its geographical distribution extends from approximately latitude 33°S on the South-East Coast to 11°S on the West Coast and off shore to a distance of 100 nautical miles. It breeds at 23 colonies between Algoa Bay in South Africa and Cape Cross 21° 45′S in South West Africa and has an estimated population size of 850 000 (Shaughnessy, in press).

An active sealing industry produces pelts and blubber oil, primarily from immature animals but also to a small extent from adult males (Best 1973; Shaughnessy, in press). An upper limit to the permissible harvest of immatures has been applied to the concessions for most colonies where seals are harvested. Many of these quotas are based on maximum sustainable yield calculated from a mathematical population model (Shaughnessy and Best, in press). In the model, no allowance is made for the mortality of seals at sea caused by fishing operations. This mortality rate may, however, be sufficiently large to influence the model as is indicated by reports of seals being caught in trawl and seine nets and brought aboard vessels (Meschkat 1956, Lambert 1975) and of shooting of seals by purse-seine fishermen operating in South West African waters out of Walvis Bay (Zur Strassen 1971, Laws 1973). Also, reports and sightings have been made of many dead seals along the coast of South West Africa (e.g. 57 dead seals were counted from a light aircraft along 70 km of coastline between Ugabmond and Cape Cross on 3 January 1975).

In this article, the incidental take (i.e. mortality and entrapment) of Cape fur seals during bottom trawling for demersal fish in South African waters south of the Orange River is assessed. In addition, data on the numbers of seals in the vicinity of trawl nets as they are hauled aboard are presented.

MATERIALS AND METHODS

Data were collected by Sea Fisheries Branch personnel on board both commercial and research trawlers during the period August 1976 — October 1978. The following information was recorded from each trawl: date; time of day; position; numbers of seals entrapped in the trawl net and brought aboard, killed by the trawling equipment, killed deliberately, and (in most instances) seen in the vicinity of the trawler when the net was hauled aboard. In practice, the latter observation was more difficult on factory stern trawlers than on side trawlers so that the data for commercial vessels are rather sparse. In addition, the whole carcass or the head alone was collected if the dead seal was brought aboard the ship.

Most of the observations were made on research cruises of the Sea Fisheries Branch side trawler

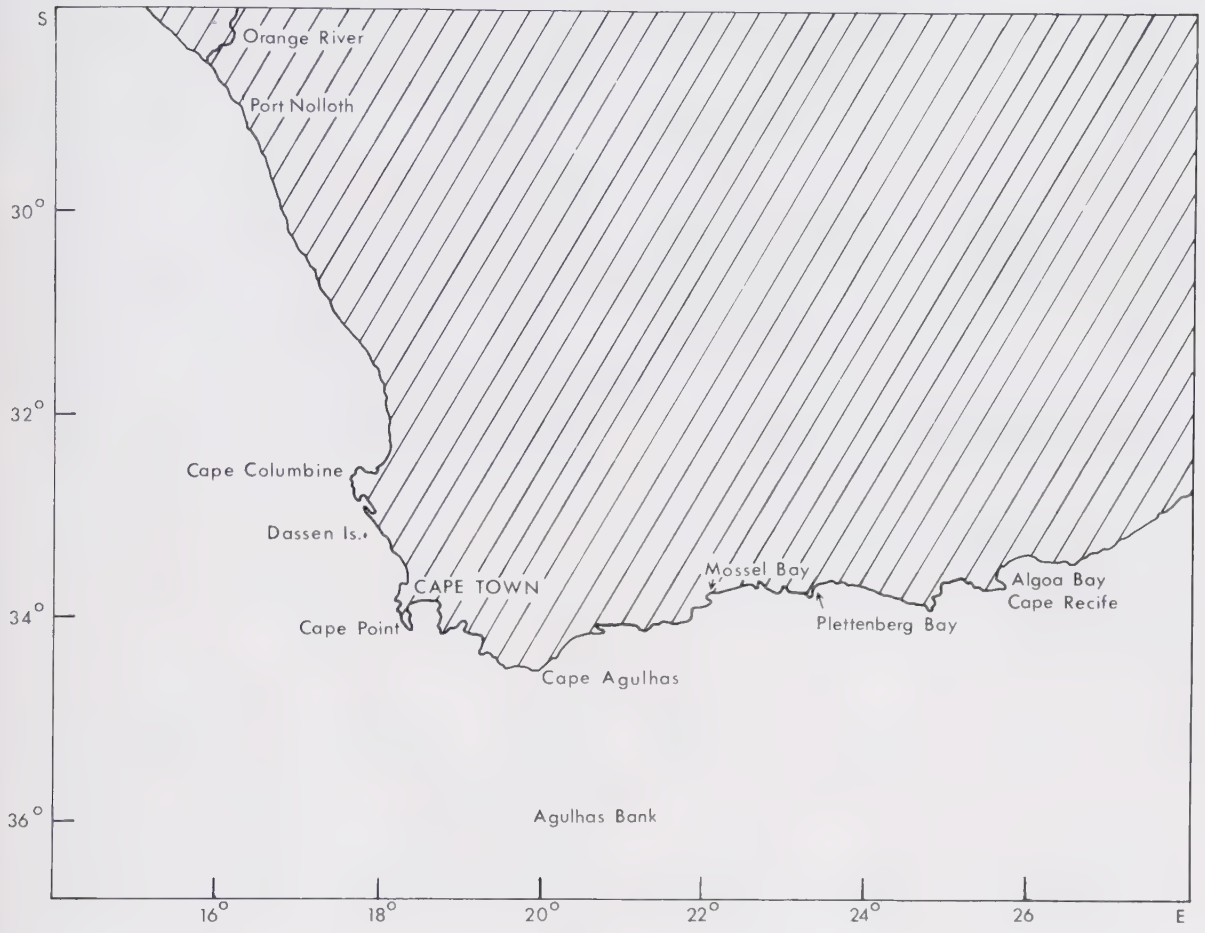

Fig. 1: Coast of South Africa showing the localities mentioned

R.S. *Africana II.* The commercial stern trawlers were manned by Sea Fisheries Branch personnel in order to sample commercial catches by species according to the areas defined by the International Commission for the South-East Atlantic Fisheries (ICSEAF).

RESULTS

The fate of Cape fur seals entrapped in nets of trawlers and the number attending nets are recorded for commercial and research vessels in Tables I and II respectively. All localities mentioned in these Tables and subsequently in the text are shown in Figure 1.

Number of seals attending trawl nets

During the study, the impression was gained that more seals attended trawlers on the West Coast than on the South Coast. This was not unexpected because there are larger seal colonies on the West Coast. Consequently, the numbers of seals recorded during trawling operations on each coast have been compared, the areas being divided by a line running south-west from Cape Agulhas.

Table I: Entrapment of Cape fur seals incidental to trawling by commercial vessels in South African waters

Vessel	Date	Location	Number of seals entrapped		Number of trawls observed	Seals at net	
			Live	Dead		Number	Mean
		West Coast					
Storesse	August 1976	Cape Town to Orange River	1	3	39		
Storesse	Nov./Dec. 1976	Cape Point	0	1	3		
Sacip	Mar./Apr. 1977	Cape Agulhas to Orange River	0	1	63		
Prima I	Jun./Jul. 1977	Cape Agulhas to Port Nolloth	3	1	32		
Storesse	Sep./Oct. 1977	Cape Agulhas to Cape Town	1	2	22		
Storesse	Sep./Oct. 1978	Cape Agulhas to Cape Town	1	0	16	95	5,9
Total			6	8	175		
		South Coast					
Storesse	Nov./Dec. 1976	Agulhas Bank	1	0	57		
Sacip	Mar./Apr. 1977	Agulhas Bank	0	2	20		
Prima I	Jun./Jul. 1977	Agulhas Bank	0	1*	22		
Storesse	Sep./Oct. 1977	Agulhas Bank	2	0	49		
Storesse & Salvia	Nov./Dec. 1977	Agulhas Bank to Algoa Bay	0	0	25	55	4,3
Storesse	Sep./Oct. 1978	Agulhas Bank	4	2	36	155	
Ocean Maid	Sep./Oct. 1978	Plettenberg Bay and Cape Recife	0	6†	10	95	
Total			7	11	219		

* killed deliberately
† 3 seals killed deliberately

Table II: Entrapment of Cape fur seals incidental to trawling by Sea Fisheries Branch research vessels in South African waters

Vessel	Date	Location	Number of seals entrapped		Number of trawls observed	Seals at net	
			Live	Dead		Number	Mean
		West Coast					
Africana II	Apr. 1977	West of Cape Town	0	3	6	194	
Benguela	Jul. 1977	West of Dassen Island	1	2	4	175	
Africana II	Oct. 1975, Mar. 1977, Feb. 1978	West of Cape Town (3 cruises of similar purpose)	1	0	3	63	
Africana II	Jan. 1978	West of Cape Columbine	1	0	4	33	10,1
Africana II	Feb. 1978	Port Nolloth to Cape Columbine	0	0	27	38	
Africana II	Mar. 1978	Cape Columbine to Cape Agulhas	1	0	17	187	
Africana II	Jun. 1978	West of Cape Town	0	1	5	69	
Africana II	Aug. 1978	Orange River to Cape Town	3	1	23	137	
Total			7	7	89		
		South Coast					
Africana II	Aug. 1976	Agulhas Bank to Algoa Bay	1	0	23	85	
Africana II	Jan. 1977	Agulhas Bank to Algoa Bay	0	0	28	163	
Africana II	Jun. 1977	Agulhas Bank to Algoa Bay	2	1	24	93	
Africana II	Sep. 1977	Agulhas Bank to Algoa Bay	2	0	25	95	
Africana II	Dec. 1977	Agulhas Bank to Algoa Bay	0	0	24	53	3,2
Africana II	Mar. 1978	Agulhas Bank to Algoa Bay	0	0	18	34	
Africana II	Mar. 1978	Agulhas Bank	0	0	2	10	
Africana II	Apr. 1978	Agulhas Bank to Algoa Bay	0	0	26	55	
Africana II	Jul. 1978	Agulhas Bank to Algoa Bay	0	0	26	60	
Africana II	Oct. 1978	Agulhas Bank to Algoa Bay	0	0	24	51	
Total			5	1	220		

During research cruises on the West Coast, an average of 10,1 seals were present per trawl (with standard error ± 1,48) compared with 3,2 (± 0,34) on the South Coast. The difference is significant (standard normal deviate = 4,53 with $P < 0{,}001$). Counts were made of seals at the trawl nets on fewer commercial cruises; again there were more seals on the West Coast (5,9 ± 1,22) than on the South (4,3 ± 0,50), but the difference was not significant (s.n.d. = 1,25 with $0{,}20 < P < 0{,}30$).

Because of the observed difference in the density of seals attending trawl nets on the two coasts, data concerning entrapment and mortality of seals were analysed for each coast separately. Furthermore, because research vessels often trawl alone away from the commercial trawling fleet, it was suspected that they would be accompanied by fewer seals than would commercial vessels. Therefore, a comparison of entrapment rate by research and commercial vessels on both coasts was also carried out.

Entrapment of seals on the West Coast

A total of 175 trawls was witnessed on six cruises of commercial trawlers. Fourteen seals were entrapped (at an average rate of 0,080 per trawl) of which eight drowned (0,046 per trawl). On eight research cruises, 89 trawls were observed and 14 seals were entrapped (0,157 per trawl) of which seven were drowned (0,079 per trawl). These data were compared statistically using the normal approximation to the binomial distribution. Neither the entrapment rates nor the mortality rates for the two types of vessel differed significantly (s.n.d. = 1,93 with $0{,}05 < P < 0{,}10$ and s.n.d. = 1,09 with $0{,}20 < P < 0{,}30$, respectively). Therefore, data from the two types of vessel have been combined to give an overall entrapment rate for vessels on the West Coast of 28 seals in 264 trawls or 0,106 seals per trawl, and an overall mortality rate of 15 seals in 264 trawls or 0,057 per trawl.

Entrapment of seals on the South Coast

A total of 219 trawls was witnessed on seven cruises of commercial vessels. Eighteen seals were entrapped (0,082 per trawl) of which seven were drowned and four killed on board giving a mortality rate of 0,050 seals per trawl. On ten research cruises, 220 trawls were observed, six seals were entrapped (0,027 per trawl) of which one was drowned (0,005 per trawl). Both the entrapment rates and the mortality rates for the two types of vessel differed significantly on the South Coast (s.n.d. = 2,53 with $0{,}01 < P < 0{,}05$ and s.n.d. = 2,94 with $0{,}001 < P < 0{,}01$, respectively). Only the rates observed on commercial trawlers were used to assess the annual entrapment and mortality of seals on the South Coast because they were considered more representative of the seal population.

Age class and sex of seals killed incidental to trawling

Material was collected from 9 of the 27 seals killed (Table III). By comparison with measurements provided by Rand (1956), two of the males (with skull condylobasal lengths of 256 and 258 mm) were judged to be large bulls and a third (with a condylobasal length of 221 mm and a body mass of

Table III: Sources and biological details of specimens of Cape fur seals killed incidental to trawling operations in South African waters

Date	Vessel	Sex	Standard length (cm)	Mass (kg)	Condylobasal length (mm)	Remarks
4 December 1976	*Storesse*	M	—	—	256	Adult
4 April 1977	*Africana II*	F	135	46	—	Mature, pregnant*
4 April 1977	*Africana II*	F	115	24	—	Immature*
4 April 1977	*Africana II*	F	132	46	—	Mature, pregnant*
21 June 1977	*Africana II*	M	—	57	221	Subadult
21 June 1977	*Prima I*	F	—	—	215	Adult
8 July 1977	*Prima I*	M	—	—	258	Adult
19 July 1977	*Benguela*	F	150	80	—	Mature, pregnant*
6 June 1978	*Africana II*	M	—	—	181	Subadult

*From inspection of reproductive tracts

57 kg) was subadult. A fourth male with a condylobasal length of 181 mm was also subadult. One female was adult judging by its condylobasal length of 215 mm. Inspection of the reproductive tracts of the other four females established that three were mature and pregnant and one was immature. Thus, six of the nine seals examined were adult. Only one of these seals (an adult male) was killed intentionally on board; the others drowned in the nets. However, this sample is too small for any conclusion to be drawn about the age class of seals killed during trawling.

DISCUSSION

During this study, 4 of the 52 seals that became entrapped in a trawl net were killed intentionally, 3 of them on one cruise. They gained access to the factory deck and could not escape overboard. Other live seals that reached the trawlers' decks escaped down the stern ramp or, in the case of side trawlers, over the side. Two seals in the water (but clear of nets) were shot while trawl nets were hauled aboard. Both had plastic straps deeply embedded in their neck and were killed for humane reasons. No other seals were shot at while observers were on these cruises.

Most of the seals entrapped entered as the nets were being hauled to the surface after trawling. On several occasions, seals were observed in the net but escaped before being hauled aboard and were thus, for the purpose of all calculations, not considered to have been entrapped. Rigor mortis had commenced in a small number of the dead seals brought aboard and it is presumed that they had entered the net at the beginning of the trawl and had drowned.

In order to estimate the number of seals killed annually by South African commercial trawlers, the number of trawls made in a year was roughly calculated in the following manner. The South African trawler fleet was first classified into five size categories (based on gross tonnage) and an example from each randomly selected. The number of trawls made by each of the five selected vessels in 1977 was counted from their demersal fishing log sheets and multiplied by the number of vessels in each category.

Two of these categories of trawlers fished predominantly on the South Coast and only a small proportion (based on the home port of the trawlers) of the total number of trawls was assigned to the West Coast. Of the other three categories of vessel (factory ships, freezers and large wet-fish trawlers), the total number of trawls on the West and South Coasts was broken down on the basis of the proportion of the total catch made in each area by the major off-shore fishing companies.

Twenty per cent of the total number of trawls thus calculated for each coast was deducted to account for trawlers that did not fish for any reason (e.g. major repair), and rough figures of 30 000 trawls (West Coast) and 50 000 trawls (South Coast) were obtained.

From the observed entrapment rates of seals on the West and South Coasts (0,106 and 0,082 seals per trawl, respectively), the annual number of seals entrapped and brought aboard by commercial trawlers was estimated as 3 180 on the West Coast and 4 100 on the South Coast, a total of 7 280. Similarly, from the observed mortality rates of 0,057 and 0,050 seals per trawl on the West and South Coasts, the annual mortality is estimated as 1 710 and 2 500 respectively, for a total of 4 210 seals. These latter figures include intentional mortalities as well as those due to drowning.

In order to determine the proportion of Cape fur seals affected annually incidental to trawling by the local industry in South African waters, an estimate of the seal population in the area covered by this study (south of the Orange River) is first required. This population can be estimated as 38 per cent of the total (Shaughnessy, in press, Table II), or 323 000 seals. The proportion of the population entrapped is then 0,023 per annum and the proportion killed is 0,013 per annum.

Entrapment of seals incidental to fishing operations has been studied in one other pinniped, the Northern sea lion *Eumetopias jubatus*. J. J. Burns (Alaska Dept. of Fish and Game, in litt.) estimates that less than 4 000 are taken annually by United States and foreign vessels in Alaskan waters. Most of these are alive and return to the sea. Since not all of the world population of this species (300 000) occur in Alaskan waters (Mate, in press), the proportion of the population entrapped is at least 0,013 per annum. This is similar to that estimated for Cape fur seals.

There are several other fisheries in the waters of southern Africa in which fishing gear may contribute to the incidental, pelagic mortality of Cape fur seals at sea: the South and South West African bottom-trawl fishery off South West Africa, the purse-seine fishery for surface shoaling fish by South African and South West African vessels and the trawl fisheries (both bottom and mid-water) by foreign vessels. As no data have been collected

from these fisheries, their contributions to the incidental mortality of Cape fur seals have not been assessed. Consequently, the estimate of 4 210 Cape fur seals killed annually incidental to trawling operations should be considered as only a fraction of the total incidental mortality.

LITERATURE CITED

BEST, P. B. 1973 — Seals and sealing in South Africa and South West Africa. *S. Afr. Shipp. News Fishg Ind. Rev.* **28**(12):49-57.

LAMBERT, K. 1975 — Beobachtungen am Zwergseebären, *Arctocephalus pusillus*, im küstenfernen Bereich vor Südwest- und Südafrika. *Zool. Garten* **45**:416-424.

LAWS, R. M. 1973 — The current status of seals in the Southern Hemisphere. *IUCN Publications New Series Supplementary Paper* **39**:144-161.

MATE, B. — History and present status of the northern (Steller) sea lion, *Eumetopias jubatus*. In *Mammals in the Seas. F.A.O. Fisheries Series 5*, vol. **3** (in press).

MESCHKAT, A. 1956 — Bei den Pelzrobben von Cape Cross. *Kosmos* **52**(10):461-467.

RAND, R. W. 1956 — The Cape fur seal *Arctocephalus pusillus* (Schreber). Its general characteristics and moult. *Investl Rep. Div. Fish. S. Afr.* **21**:52 pp.

SHAUGHNESSY, P. D. — The status of seals in South Africa and South West Africa. In *Mammals in the Seas. F.A.O. Fisheries Series 5*, vol. **3** (in press).

SHAUGHNESSY, P. D. and P. B. BEST — A discrete population model for the South African fur seal, *Arctocephalus pusillus pusillus*. In *Mammals in the Seas. F.A.O. Fisheries Series 5*, vol. **3** (in press).

ZUR STRASSEN, W. H. 1971 — *The Fur Seal of Southern Africa*. Cape Town; Howard Timmins: 71 pp.

Fish. Bull. S. Afr. 12:26—34
26 *1979*

A SURVEY OF THE STOCK OF THE SOUTHERN AFRICAN WEST COAST SOLE *AUSTROGLOSSUS MICROLEPIS* BETWEEN 28°30'S AND 32°S

A. I. L. PAYNE

A brief history of the fisheries for soles in South Africa is given and the decline in stocks of West Coast sole in the area 27 — 33°S is illustrated. A survey was made of this stock in August 1978 and the research catch rates of the main species caught (sole, hake, gurnard and St Joseph shark) are given. The length distribution and the catch rate showed a high density of baby soles in the north of the survey area but only a sparse scattering of mature soles in the south. Age readings showed that most soles were two or three years old. The length at 50-per-cent maturity (24 cm) was lower than that described for a stock to the north of the survey area. It is estimated that, in three years time, the main age groups caught during this survey (2, 3 and 4 years) will represent a stock of 104 — 336 metric tons with assumed natural mortality coefficients (M) of 0,1 — 0,5. If the sampling is considered unrepresentative because of the lower efficiency of an otter trawler compared with a beam trawler, the stock of these age groups after three years could be as high as 417 — 1 383 tons depending on the value of M.

Die geskiedenis van die visserye na tongvis in Suid-Afrika word kortliks verstrek en die afname van die voorraad Weskus-tongvis in die gebied 27 — 33°S word geïllustreer. 'n Opname is van die stapel gemaak, en die vangstempo van die vernaamste spesies eksperimenteel gevang (tongvis, stokvis, knorhaan en St Josef-haai) word verstrek. Die lengteverbreiding en die vangstempo het 'n hoë digtheid van klein tongvissies in die noorde van die opnamegebied aangedui, maar slegs 'n yl verspreiding van volwassenes in die suide. Ouderdomsaflesings het aangetoon dat die meeste tongvis twee of drie jaar oud was. Die lengte waarby 50 persent volwasse was (24 cm), was laer as dié wat vir 'n stapel noord van die opnamegebied beskryf is. Daar word bereken dat die bevolking van vis 2, 3 en 4 jaar oud met veronderstelde natuurlike sterftesyfers (M) 0,1 — 0,5 oor drie jaar 'n voorraad van 104 tot 336 metrieke ton sal verteenwoordig. As die bemonstering as onverteenwoordigend beskou word, weens die ondoeltreffendheid van 'n ottertreiler vergeleke met 'n balktreiler, mag die voorraad van dié ouderdomsgroepe oor drie jaar so hoog as 417 — 1 383 ton wees, afhangende van die waarde van M.

The sole fishery of South Africa is historically based on two species, the West Coast or "super" sole *Austroglossus microlepis* and the Agulhas sole *A. pectoralis*, whereas the fishery of South West Africa depends on the West Coast sole only. Both these species are true soles (family Soleidae), i.e. with eyes on the right side and pectoral fins present (Smith 1965). Recently, however, landings have been supplemented by catches of the sand sole *Trulla capensis*, particularly on the Cape south coast. This species is not a true sole but belongs to the family Cynoglossidae (eyes on the left, no pectoral fins). The contribution made by this species to the annual sole landings is unknown because its landings have been included with those of the true soles.

Although soles account for less than 2 per cent of the South African annual trawlfish catch, they are by far the most valuable fish per unit weight landed (Botha 1970) and are therefore the principal target of the small trawlers, particularly along the South Coast.

The history of the fishery for the Agulhas sole has been well documented by Scott (1950) and Zoutendyk (1973), and a stock assessment of the species has been made by Botha (1977). Based on this stock assessment, a quota for sole of 700 metric tons landed weight (mass) was fixed for 1978. This quota is applicable to Agulhas sole caught east of Cape Hangklip (19°E).

In contrast to the Agulhas sole fishery and stocks, little has been published about the West Coast sole. However, because the Agulhas sole quota was filled as early as mid-August in the first year of application, and because requests temporarily to transfer fishing effort to the West Coast after quota completion may be anticipated, the Sea Fisheries Branch conducted a pilot survey of the West Coast sole stocks between 28°30'S and 32°S.

THE FISHERY AND STOCKS OF EAST COAST SOLE

From an evaluation of catch statistics, at least two geographically discrete stocks of *A. microlepis* seem to exist. The northernmost of these (hereafter called the northern stock) is found between latitudes 19°S and 25°S and makes a significant contribution to the small trawl fishery of South West Africa (Lucks *et al.* 1973). The southern stock lies between latitudes 27°S and 33°S, though the most dense

concentrations were historically found between 28°S and 30°S.

A mesh selectivity study was conducted on the northern stock (Lucks 1972), and the conclusion reached, based on age-at-maturity, was that a mesh size of 75 mm should be applied to the fishery. However, since 1 July 1975, all trawlers fishing in the South-East Atlantic Ocean have been compelled to use a net with a minimum mesh size of 110 mm when catching more than 30 per cent by weight of hake, and because of the mixed nature of the fishery for the northern stock of sole, trawlers using an otter trawl have been prohibited from using the smaller mesh size. The few beam trawlers operating in the area are permitted to use a 75 mm mesh by virtue of their low-opening net and, thus, their vastly decreased by-catch of hake. The southern limit of this stock is not known, though O'Toole (1977) stated that the area between 22 °S and 24 °S is an important spawning location.

Although the northern stock is found in depths ranging from 75 m to 300 m (Lucks *et al.* 1973, and unpublished Sea Fisheries Branch catch statistics), the southern stock was in the past only fished in depths of 50-100 m, little being caught in deeper water. Also, though the fishery on the northern stock is a comparatively recent innovation (the trawl fishery only commenced out of Walvis Bay in 1958), the fishery on the southern stock was established many years before and regular landings have been recorded since the 1930s.

The annual landings of each of the sole stocks and species in the period 1963-1978 are shown in Table I.

Table I clearly reflects the growth and the subsequent decline of the fishery for the northern stock of West Coast soles. In recent years, the fishery has become much more hake-orientated and fishing for soles, because of decreasing availability, has become commercially less profitable, although a reversal of the trend was evident in 1978.

The southern stock declined rapidly from a peak of landings in 1966, and since 1974 only an insignificant proportion of the total sole catch has been derived from this area (Table I). Fishing was carried out predominantly from Port Nolloth, and decreasing catch rates are implied by the reduction in the number of bottom trawlers registered at the port between 1967 and 1973 (Sea Fisheries Branch 1969-1974):

Year	1967	1968	1969	1970	1971	1972	1973
Number of trawlers	12	14	9	4	4	1	0

Table I: Annual landings (metric ton) of each of the commercially exploited sole stocks

Year	West Coast sole *Austroglossus microlepis*		Agulhas sole
	Northern stock (19 — 25°S)	Southern stock (27 — 33°S)	*A. pectoralis*
1963	100 — 150*	1 066	704
1964	100 — 150*	608	664
1965	100 — 150*	954	808
1966	150	1 404	551
1967	725	534	587
1968	1 062	244	426
1969	953	301	615
1970	1 162	365	635
1971	578	45	843
1972	1 379	121	1 004
1973	1 895	133	924
1974	897	41	588
1975	520	5	733
1976	178	+	1 000
1977	272	6	780
1978	836	+	995

*estimated + less than 0,5 metric tons

The southern stock has been subjected to occasional experimental fishing by commercial trawlers in the past few years, but an evaluation of the present state of the stock has not been made. The Sea Fisheries Branch therefore decided to carry out a survey with the conventional bottom trawler R.S. *Africana II*, and the results of this survey, in August 1978, are presented here.

MATERIAL AND METHODS

The area of survey, covering only the southern stock and incorporating the positions at which each trawl was made, is shown in Figure 1. Most trawling was carried out in the northern sector of the area for two reasons: firstly, most historical catches were made in this region and, secondly, trawling in the south is impeded by an exceptionally heavy substratum and many fasteners. Once the area of survey had been decided upon, the positions of the individual trawls were randomly selected within the chosen depth contours (50-100 m). Trawling was carried out for an hour at a time and conventional gear was used but with the 75-mm-mesh codend of the net lined on the inside with 27,5-mm-mesh pilchard netting.

The total weight (mass) of each species brought on board ship was determined to the nearest kilo-

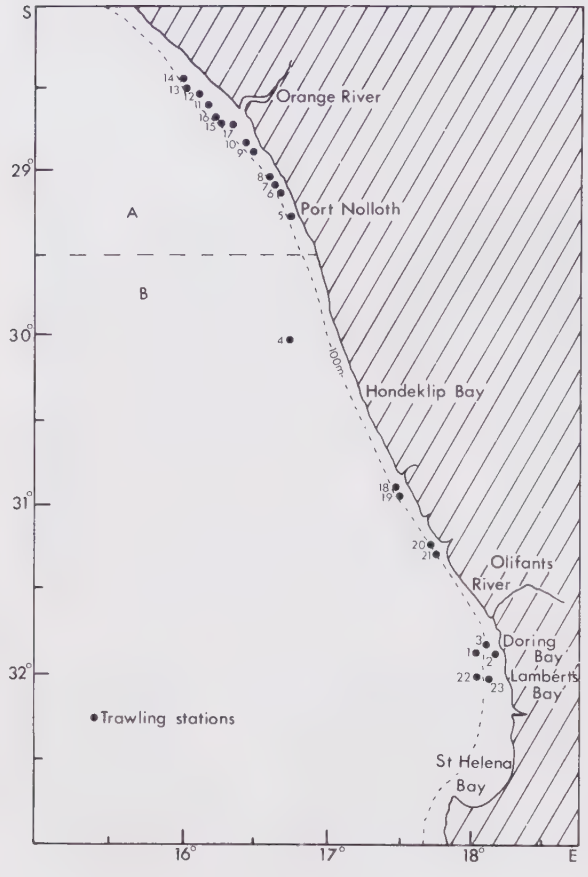

Fig. 1: Trawling stations occupied on a survey of the southern stock of West Coast sole, August 1978 (A — northern sector, B — southern sector)

gramme using a spring balance shackled to a boom of the ship. Weather conditions were good and permitted fairly accurate readings of weight to be attained. On two occasions, the volume of the trawl was too large to weigh the entire catch quickly. An estimated proportion of the total was taken as a subsample and the subsequent analysis weighted accordingly. A count was made, either of the total number of each species, or of a known weight when the size range of that species was limited and the catch large.

All soles were sampled for length distribution (each trawl), age (2 fish per total length class of 10 cm per trawl) and sex and stage of maturity (10 fish per length class of 10 cm per trawl).

RESULTS

Catch composition

The main species caught were hake *Merluccius capensis*, West Coast sole *Austroglossus microlepis*, gurnard *Trigla* spp. and St Joseph shark (now marketed as silver trumpeter) *Callorhyncus capensis*. The sampling circumstances for each trawl, the weight per hour trawled, number per hour, mean weight (to give an idea of size category) and percentage by weight of the total catch for each of the main trawled species are given in Table II.

Sole catches were widespread but much larger in the northern sector of the survey area. There was no evident variation in catch rate by depth although the largest catches of sole did come from the shallower water. However, the average weight of individual soles increased with depth.

Catches of hake were also widespread, though the larger catches were made in the north. All hake were small, very few mature fish being caught. Hake catches were, in general, greater in water deeper than 70 m, that species accounting for a maximum of 12 per cent of the total catch of each trawl in water shallower than this. In only five of the 19 trawls made in water deeper than 70 m was the percentage of hake less than 30 per cent.

Of the other two species caught in quantity, only St Joseph shark was of a size suitable for human consumption. This species was widespread and accounted for up to 82 per cent of the catch (mean for the survey was 17,7 per cent). Gurnards were always present but on only one occasion abundant, and the sizes caught were usually too small to allow for direct human consumption.

A few kingklip *Genypterus capensis*, various sharks and skates, gobies *Sufflogobius bibarbatus* and mantis shrimps *Squilla armata* made up the balance of each trawl catch. The latter two species were being preyed upon heavily by most of the fish caught, though not by soles. Polychaetes were found in the stomachs of many soles.

Length distribution

The length distribution of 2-cm length classes in the sole catch is reflected in Figure 2. Catches south of 30°S (southern sector) and north of 30°S (northern sector) are shown separately. As mentioned previously, the catch of soles in the southern sector was small, but consisted mainly of fish in the 30-40 cm length range and well within the size

Table II: Trawl and catch data for each station sampled

Station	Date (Aug. '78)	Initial depth (m)	Bottom temp. (°C)	Total weight caught (kg)	Hake				Sole				Gurnard				St Joseph			
					Wt/h (kg)	No./h	Av. wt (g)	%	Wt/h (kg)	No./h	Av. wt (g)	%	Wt/h (kg)	No./h	Av. wt (g)	%	Wt/h (kg)	No./h	Av. wt (g)	%
1	10	104	8,9	173	146	1 168	125	84,4	5	9	556	2,9	13	56	232	7,5	9	5	1 800	5,2
2	10	77	9,9	475	334	3 278	102	70,4	5	14	357	1,1	24	81	296	5,1	91	54	1 685	19,2
3	10	82	9,0	436	116	1 271	91	44,3	5	13	409	2,1	18	28	652	6,9	97	62	1 558	37,2
4	11	137	9,4	34	10	138	71	26,7	—	—	—	—	2	8	286	5,9	24	20	1 222	65,2
5	11	77	8,9	118	13	116	115	18,7	27	264	101	37,4	5	9	533	6,8	19	12	1 550	26,4
6	12	76	8,2	444	265	1 947	136	59,8	27	214	126	6,1	20	61	328	4,5	84	60	1 400	18,9
7	12	75	8,7	1 309	845	5 708	148	65,6	10	86	115	0,8	91	289	313	7,0	285	216	1 318	22,2
8	12	77	8,6	1 629	1 078	7 464	144	67,3	7	43	159	0,4	113	425	266	7,1	366	265	1 383	22,8
9	12	77	8,9	247	29	186	156	11,7	32	547	59	13,0	73	276	265	29,6	103	49	2 102	41,7
10	12	66	9,1	266	36	268	133	12,0	67	1 316	51	22,6	69	292	236	23,3	121	50	2 422	41,0
11	13	54	8,7	2 048	3	21	143	0,1	284	3 302	86	13,9	44	287	153	2,1	1 692	1 082	1 564	82,6
12	13	54	8,9	621	18	103	170	2,7	131	1 577	83	20,5	73	331	222	11,4	403	363	1 111	62,8
13	13	82	8,9	1 287	1 138	3 426	332	88,4	71	594	120	5,5	44	114	386	3,4	29	18	1 611	2,3
14	13	82	8,7	6 577	5 830	35 206	166	81,3	79	436	180	1,1	847	4 189	202	11,8	340	200	1 696	4,7
15	14	95	8,8	173	101	574	177	41,0	34	156	220	13,9	16	44	355	6,4	31	23	1 375	12,7
16	14	99	8,9	35	22	62	350	60,0	—	—	—	—	5	8	625	14,3	6	3	2 000	17,1
17	14	51	9,0	87	2	16	94	1,7	4	26	154	4,6	26	129	202	30,1	50	25	2 000	57,8
18	15	88	8,5	194	46	309	149	23,7	7	4	1 750	3,6	72	126	571	37,1	61	67	910	31,4
19	15	97	8,5	222	17	149	116	7,7	—	—	—	—	91	318	284	40,1	108	91	1 191	47,7
20	15	99	8,3	313	154	1 142	135	49,2	1	4	250	0,3	46	164	281	14,7	54	44	1 227	17,3
21	15	97	8,3	329	309	2 387	129	76,6	—	—	—	—	55	159	346	13,7	36	29	1 208	8,8
22	16	106	8,2	278	167	1 396	120	62,3	1	3	167	0,2	51	97	530	19,1	47	10	4 800	17,3
23	16	98	8,1	59	26	163	158	40,7	—	—	—	—	17	68	254	27,1	18	11	1 700	28,8

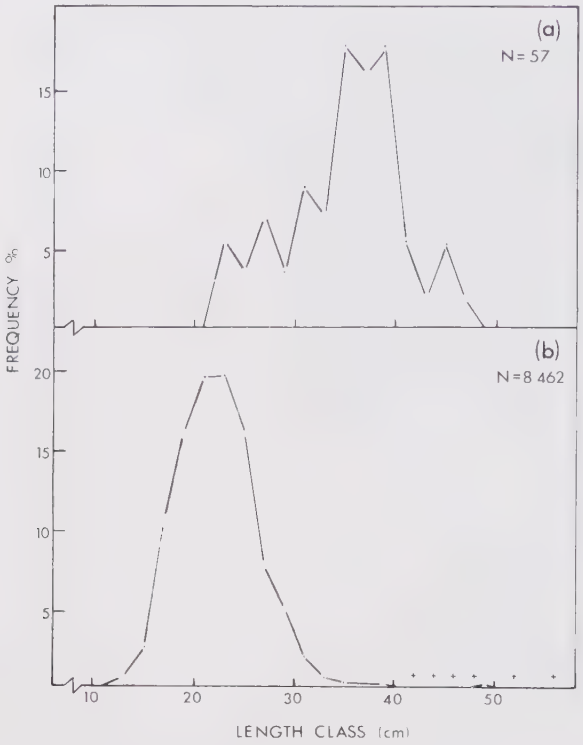

Fig. 2: Percentage frequency of 2-cm length classes of West Coast sole — a) southern sector 30-32°S b) northern sector 28-30°S

range sought by the industry.

However, the catch in the northern sector, where sole availability was greatest, consisted of fish between 15 cm and 30 cm long. The peak of these (18-25 cm long) only just fell within the range currently processed by the industry. From length-distribution studies on the Agulhas sole, conducted at Mossel Bay during the second half of 1977, slips (the smallest category of sole landed) were found to have a length range of 22-32 cm with a peak at 28 cm. It is assumed that a similar acceptability can be applied to the West Coast sole. Also, the mesh size of the net currently used by the industry, 75 mm, would allow most West Coast soles shorter than 30 cm to escape (Lucks 1972). Thus, the length range of soles at present predominating in the northern sector would not warrant a stepping-up of effort by the industry in this area.

Age composition

There is no published information on age determination of the West Coast sole. However, Zoutendyk (1974) made a study of the growth rate of the Agulhas sole and, because the age composition of the catch was regarded as essential to this study, his method of preparation of otoliths and his interpretation has been applied to the limited data collected on the congeneric West Coast species.

A total of 78 pairs of otoliths was collected, covering both sexes and a wide range of fish lengths. The limited number of otoliths taken resulted from the collection procedure which entailed collecting two fish per 10-cm length class per trawl. In most trawls, however, the length distribution was limited and only five or six fish were sampled. The otoliths were interpreted by two persons and, if agreement was reached, the reading was taken as the age of the fish. A third, later reading was made if agreement was not reached and two similar readings were then taken to represent the age. Only 11 (14 per cent) did not agree in any of the three readings and were therefore discarded.

The mean length-at-age was calculated (Table III) and, grouping the data into 2-cm length classes, a plot was made of the age composition of the catches (southern and northern sectors combined). This is shown in Figure 3.

The main age groups present in the catch were two and three year olds (15-25 cm total length). These would be too small for processing by the industry. Only the longer of the four-year-old fish would be retained by unlined codends with a mesh size of 75 mm. Therefore, even the four-year-old fish would be unable to make a significant contribution to the total catch. Fish five years of age and more would be commercially acceptable but are in short supply. Soles younger than two years of age would be expected to have escaped through the meshes of the experimental net and thus, the lack

Table III: Mean length-at-age for a sample of West Coast sole

Age	Mean length-at-age	Number read
0	—	0
1	12,5	1
2	17,9	18
3	23,5	12
4	26,2	6
5	34,2	7
6	37,9	8
7	42,3	5
8	44,4	7
9	48,5	2
10	—	0
11	—	0
12	55,5	1

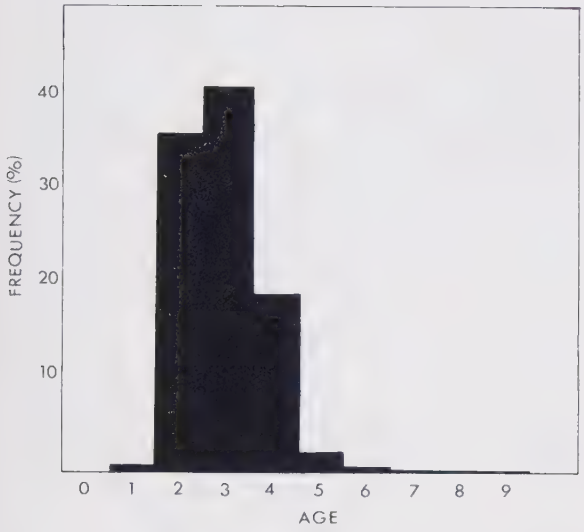

Fig. 3: Age composition of the research catch of West Coast sole, August 1978

of these fish in the catches does not necessarily indicate their absence from the stock.

If the current growth rate is maintained, as seems likely, the stock of commercially exploitable soles in the area (particularly the northern sector) could, if migration is limited and natural mortality low, be large enough after three years to warrant a resumption of trawling activity. This would also, of course, be subject to a limitation on fishing activity in the meantime.

Sexual maturity

A total of 634 soles of both sexes from 12 cm to 55 cm long was examined for stage of maturity and the results are given in Table IV.

Excessive fishing can shorten the time taken for a species to mature. The length at 50-per-cent maturity indicated by Table IV (24 cm) was lower than that found by Lucks (1972) although the stock studied was not the same. In his work on the northern (19-25°S) stock of West Coast sole, Lucks (*op. cit.*) concluded that the length at 50-per-cent maturity for the species was 29 cm.

In this study, it was found that males matured earlier (length at 50-per-cent maturity 23,5 cm) than females (± 25 cm) as is the case for the Agulhas sole (Zoutendyk 1974), the kingklip *Genypterus capensis* (Payne 1977) and many other fish species.

Table IV: Numbers of immature and mature soles at specific lengths (sexes combined)

Total fish length (cm)	Number of soles		Total
	Immature	Mature	
12,5	1		1
13,5	2		2
14,5	1		1
15,5	6		6
16,5	19		19
17,5	30		30
18,5	53		53
19,5	57		57
20,5	19	2	21
21,5	30	1	31
22,5	24	10	34
23,5	17	16	33
24,5	14	16	30
25,5	8	20	28
26,5	5	20	25
27,5	5	17	22
28,5	3	24	27
29,5		24	24
30,5		36	36
31,5		35	35
32,5	1	20	21
33,5		18	18
34,5		22	22
35,5		10	10
36,5		9	9
37,5		10	10
38,5		4	4
39,5		7	7
40,5 — 55,5		18	18

Seventeen females (5,0 per cent of the females sampled) were in a ripe condition and one each (0,3 per cent) in a ripe-running and a spent condition. This indicates that the main spawning season would probably have begun in late August shortly after the survey.

Catch rate

The catch rate of sole in the northern sector was 54,0 kg/hour. The 10 trawling stations south of 30°S were excluded as they were considered unrepresentative of the stock as a whole. For the purposes of comparison, the catch rate of Agulhas sole by the same research trawler on the grounds between 20°E and 20°40'E was calculated. The results are given in Table V. The data for April 1975 were obtained using precisely the same gear, but those for August 1971 are the result of a mesh selectivity experiment (Botha *et al.* 1971) in which a codend with a nominal mesh-size of 80 mm was used with a covernet of 40-mm mesh. The catches

Table V: Relevant research trawl information and catch rates of West Coast sole north of Port Nolloth and of Agulhas sole in the grounds between 20°E and 20°40'E

Species	Date sampled	Number of trawls	Duration of trawls	Sole catch rate (kg/h)
Agulhas sole	August 1971	8	2 – 2½ h	20,1
Agulhas sole	April 1975	6	1 h	10,7
West Coast sole	August 1978	13	1 h	54,0

of covernet and codend were combined for the purposes of calculating the catch rate.

The catch rate of West Coast sole was much higher than either of the rates calculated for Agulhas sole. However, the vast majority of the catch of West Coast sole was made up of small fish less than 30 cm long (Fig. 2b). In the case of the Agulhas sole, on both occasions the percentage of the total number of fish caught that were less than 30 cm long was about 50 per cent.

Figure 4 reflects the number of fish (in 2-cm length classes) caught per hour on each of the three surveys. Because a net with the legal minimum mesh size of 75 mm allows most fish smaller than 30 cm long to escape (Botha *et al.* 1971, Lucks 1972), it would appear to be economically more feasible, on the basis of these three surveys, to continue exploiting the Agulhas sole stock.

The catch rates calculated here should not be compared with commercial catch rates (Botha 1977) for three reasons. Firstly, the commercial catch rate excludes any fish too small for marketing, few of which are caught because of the size of the mesh used in the codend. Secondly, the duration of commercial trawls is generally longer than 1-2 hours, increasing the likelihood of masking of the net taking place. Finally, the random sampling system employed in research operations can not yield the consistently large catches sought after commercially. Most trawler skippers, once they have identified a spot where catches are good, will continue to work that area until the catch rate drops.

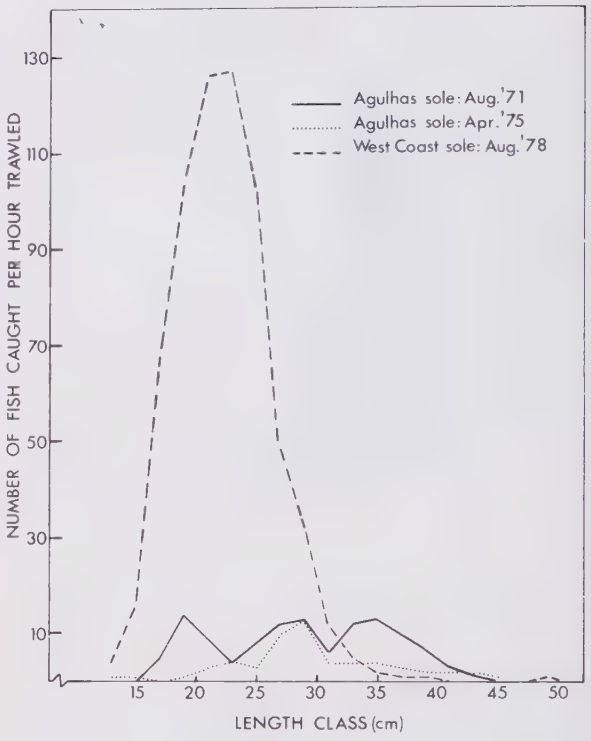

Fig. 4: Number of fish per 2-cm length class caught per hour on three separate sole surveys

DISCUSSION

Although based on only a single survey, certain theoretical conclusions regarding potential stock size may be drawn in order to give a basis for an evaluation of the future economic feasibility of exploiting the stock.

The area of most intense survey (28°30'S – 29°30'S) is used for the calculations although the stock may extend as far north as 27°S. South of 29°30'S the density of sole, particularly of small sole, is less and this area may therefore be disregarded as a potential resource.

At each of the 13 trawling stations in the northern sector, trawl time was one hour and the ship averaged 3 knots thus covering ± 3 nautical miles. The net can be assumed to have fished a 100-m swath. Thus, a total area of $72{,}275 \times 10^5$ m² was covered. The distance between the 50 and 100 m depth contours (the sole grounds) averages 5 nautical miles and the length surveyed covered 75 miles. The total area would thus be 375 square miles or $1{,}288 \times 10^9$ m². Although soles are patchy in distribution, the density deduced from the limited area surveyed is considered representative of the whole area because the nature of the substratum is the same throughout. Thus, a raising factor was calculated to bring the density of the surveyed area to that of the whole area:

$$\frac{\text{Total area}}{\text{Surveyed area}} = 178{,}2$$

Because fish two, three and four years old predominated in the catch, the raising factor was applied to the number of soles caught in each of these age classes and, using the mean length-at-age data presented earlier (Table III), converted to weight by means of the relationship calculated by Chalmers (1976). The results were 17,3 metric tons of fish of age 2, 46,0 tons of age 3 and 29,6 tons of age 4 now present in the stock.

Most fish 30 cm and smaller would be released by a net with a mesh size of 75 mm (Lucks 1972). Also, 50 per cent of the total survey area lies within 5 miles of the coast and is therefore legally closed to trawling operations. For these two reasons, it seems unlikely that the stock will become commercially viable for at least three years and therefore it was considered reasonable to assess the stock size of these age classes in three years time.

With fishing mortality accepted as nil, emigration slight (West Coast sole are not thought to be particularly prone to migrations under normal circumstances), only natural mortality (M) can be expected to reduce the stock to any degree. Sole are not preyed upon very heavily, though they have been found in the stomachs of snoek (Nepgen 1979) and kingklip. M is thus expected to be low but, because no assessment of this parameter has been made for *A. microlepis*, a few projections were made. The first of these was based on the mortality coefficient estimated by Beverton and Holt (1956) for the North Sea plaice *Pleuronectes platessa*. They stated that 0,1 would be a fair estimate of M in the case of this flatfish and that "the true value is unlikely to be much higher" (*op. cit.* p. 391). After three years of growth, the fish two, three and four years old would, assuming M = 0,1, account for a stock size of West Coast sole five, six and seven years old of 346 metric tons.

The natural mortality calculated from the age composition of the catch (Fig. 3) is high. For example, a value of M of 0,78 is indicated by the reduction in number between fish three and four years old. Incorrect age readings could result in an unusually high mortality rate but, in this case, are not suspected. More likely, the calculation of M has been biased by comparison of different year-classes at the same time and not following a particular year-class over a period of time, which would be more accurate. After the depression of the stock size to a level where fishing was no longer an economic proposition, a recovery appears to be taking place and a few strong year-classes have resulted from successful spawning and subsequent larval settlement in 1974 and, more particularly, in 1975 and 1976. It is possible, of course, that natural mortality in a recovering stock could be greater and, thus, other projections were made with higher values of M, though not as high as 0,78 for the reasons mentioned above. Assuming that growth and all other factors remain the same, the stock of fish 2-4 years old would, in three years, realize a stock of fish 5-7 years old of 256, 190, 141 or 104 tons with mortality rates of 0,2, 0,3, 0,4 and 0,5 respectively.

The projections are based on the sampling efficiency of a conventional otter trawler. Beam trawlers are 3,5 times more effective at catching Agulhas soles than conventional trawlers (Botha 1977). A preliminary survey on the effectiveness of beam trawlers catching West Coast sole indicates an increase of efficiency of 4-8 times over the conventional trawler (Botha and Payne, in press). Thus, if the sampling was unrepresentative by four times, as a conservative estimate, the stock sizes of fish five, six and seven years old after three years could be 1 383, 1 025, 759, 562 or 417 tons at natural mortality coefficients of 0,1, 0,2, 0,3, 0,4 and 0,5 respectively. None of these figures represent an economic stock size and exploitation is therefore unlikely to be worthwhile if based only on these year-classes.

Many of the three-year-old fish were spawning for the first time and, if fishing activity is still curtailed, they will have had the opportunity to spawn several times before fishing again becomes economical, a healthy prospect for the future resumption of the fishery.

The northward extent of the population has not been delimited, though soles are apparently caught up to latitude 27°S. The absence of small soles in the south is difficult to comprehend because, from the examination of gonads, spawning is taking place. Possibly, the north-flowing Benguela current carries the planktonic stages up to the northern sector of the survey areas where metamorphosis and settlement take place.

CONCLUSIONS AND RECOMMENDATIONS

Indications are that fishing of the southern stock of West Coast soles will not become economically viable for some years.

A recovery appears to be taking place, but continued curtailment of fishing activity is necessary in order that the permanence and extent of the recovery can be monitored. The existing prohibition

on trawling within five miles of the West Coast up to the Cunene River will help, particularly on the South African side where 80 per cent of the sole grounds lie inside the closed limit. On the South West African side, however, the position is reversed and other control measures will be necessary in order to protect the stock from excessive exploitation.

It is considered vital that the reproductive cycle, the dispersal and migration patterns, if any, and the growth rates be studied in order to obtain a better understanding of the interrelationships between the dense, northern-sector stock of young fish and the sparse scattering of larger fish in the south. Follow-up surveys will help to determine a more accurate value of M and will go a long way towards determining whether the recovery is permanent or based on just a few apparently strong year-classes. Only then will an objective estimate of optimum sustainable yield of the sole fishery become a feasible proposition.

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LITERATURE CITED

BEVERTON, R. J. H. and S. J. HOLT 1956 — The theory of fishing. In *Sea Fisheries: their investigation in the United Kingdom.* Graham, M. (Ed.). London; Arnold: 372-441.

BOTHA, L. 1970 — S.A. trawlfish landings from 1955 to 1968 with special reference to the hake. *S. Afr. Shipp. News Fishg Ind. Rev.* **25**(1):68-77.

BOTHA, L. 1977 — Assessment of Agulhas sole stocks, Cape Agulhas to East London. *S. Afr. Shipp. News Fishg Ind. Rev.* **32**(12):39-41.

BOTHA, L. and A. I. L. PAYNE — Comparative catching efficiency of beam trawls and otter trawls on demersal fish stocks off South West Africa. *Fish. Bull. S. Afr.* **13** (in press).

BOTHA, L., LUCKS, D. K. and D. S. CHALMERS 1971 — Mesh selectivity experiments on the East Coast sole. *S. Afr. Shipp. News Fishg Ind. Rev.* **26**(10):50-57.

CHALMERS, D. S. 1976 — Weight conversion factors, length/weight relationships and annual landings of some South African trawl-caught fish. *Fish. Bull. S. Afr.* **8**:1-4.

LUCKS, D. K. 1972 — Mesh selectivity studies on sole off South West Africa. *S. Afr. Shipp. News Fishg Ind. Rev.* **27**(9):54-57.

LUCKS, D. K., PAYNE, A. I. L. and S. MAREE 1973 — The trawl fishery of South West Africa. *S. Afr. Shipp. News Fishg Ind. Rev.* **28**(9):65-71.

NEPGEN, C. S. de V. 1979 — The food of the snoek *Thyrsites atun. Fish. Bull. S. Afr.* **11**:39-42.

O'TOOLE, M. J. 1977 — Development and distributional ecology of the larvae of the West Coast sole *Austroglossus microlepis. Fish. Bull. S. Afr.* **9**:32-45.

PAYNE, A. I. L. 1977 — Stock differentiation and growth of the Southern African kingklip *Genypterus capensis. Investl Rep. Sea Fish. Brch S. Afr.* **113**:32 pp.

SCOTT, P. 1950 — Otter-trawl fisheries of South Africa. *Geogrl Rev.* **40**(1):529-551.

SEA FISHERIES BRANCH 1969 to 1974 — Annual Reports for the years 1967 to 1973: Administration. *Rep. Sea Fish. Brch S. Afr.* **35-41.**

SMITH, J. L. B. 1965 — *The Sea Fishes of Southern Africa. 5th Ed.* Cape Town; Central News Agency: 580 pp.

ZOUTENDYK, P. 1973 — The biology of the Agulhas sole, *Austroglossus pectoralis.* 1. Environment and trawling grounds. *Trans. R. Soc. S. Afr.* **40**(5):349-366.

ZOUTENDYK, P. 1974 — The biology of the Agulhas sole, *Austroglossus pectoralis.* 2. Age and growth. *Trans. R. Soc. S. Afr.* **41**(1):33-41 + Plate 1.

Fish. Bull. S. Afr. 12:35—43
1979

TRENDS IN THE LINE FISHERY FOR SNOEK *THYRSITES ATUN* OFF THE SOUTH-WESTERN CAPE, AND IN SIZE COMPOSITION, LENGTH-WEIGHT RELATIONSHIP AND CONDITION

C. S. DE V. NEPGEN

Traditionally the majority of snoek were caught off the West Coast, but in recent years they have become more available east of Cape Point. Tag recoveries indicated only random local movement. Fork lengths varied between 52 cm and 113 cm and weights between 710 g and 6 924 g. There was a slight decrease in mean annual fork length. By number of fish, the annual trends in catch per unit effort from 1970 to 1978 at three localities do not indicate decreased availability or overfishing. The regression equation describing the length-weight relationship for both sexes combined was $W = 0{,}0204\ L^{2{,}6940}$. The mean, monthly, relative condition factor was high from March to May and low from August to November, the seasonal changes being related to the spawning cycle. A table was compiled for determining the theoretical weight of snoek for each centimetre length in each month of the year.

Die meerderheid snoek is tradisioneel langs die Weskus gevang, maar gedurende die laaste paar jaar was hulle meer beskikbaar oos van Kaappunt. Merkherwinnings het slegs plaaslike trekbewegings sonder bepaalde patroon aangedui. Die vurklengtes van die snoek wat ondersoek is, het tussen 52 cm en 113 cm gewissel en die gewigte tussen 710 g en 6 924 g. Daar was 'n geringe vermindering in die jaarlikse gemiddelde vurklengtes, maar die jaarlikse vangs per pogingseenheid vanaf 1970 tot 1978 by drie lokaliteite het nie 'n afname in beskikbaarheid of oorbevissing getoon nie. Die regressievergelyking van die lengtegewigsverhouding van albei geslagte tesame is $W = 0{,}0204\ L^{2{,}6940}$. Die gemiddelde, maandelikse, relatiewe kondisie faktor was hoog vanaf Maart tot Mei en laag vanaf Augustus tot November, en die seisoenwisselinge hou verband met die kuitskietsiklus. 'n Tabel is opgestel waarvolgens die teoretiese gewig van snoek vir elke sentimeter lengte in elke maand bepaal kan word.

The South African snoek *Thyrsites atun* (Euphrasen) belongs to the family Gempylidae and is conspecific with the New Zealand barracouta and closely related to the Australian snoek *Leionura atun* and the sierra *Thyrsitops lepidopodea* of southern South America.

It is a migratory species, appearing in and disappearing from specific areas during the year. In recent years, it has been caught from Walvis Bay (23°S) in the north to Walker Bay (19°E) on the South-East Coast in cool temperate waters where the mean sea surface temperatures fluctuate between 12 and 18°C. Occasionally, small catches are made as far east as Mossel Bay (22°E). The snoek season reaches a peak along the South West African coast during November, December and January and along the Cape west coast from April to July. East of Cape Point, the peak appears over the period June to October.

Snoek are of considerable economic importance in South Africa and the annual value to the line fishermen of the catch during an open season 1 December-31 July) has recently exceeded R2 000 000. The annual landings made by the line-fishing boats since 1897 are presented, where available, in Table I. These figures have been compiled from reports by the Government Biologist of the Cape of Good Hope, of the Fisheries and Marine Biological Surveys and of the Division of Sea Fisheries, and from catch statistics collected by the Sea Fisheries Branch. Also, bottom trawlers usually land between 700 000 and 1 000 000 snoek each year.

Table I: Available annual snoek landings, 1897-1978

Year	Number landed	Year	Number landed
1897	436 733	1931	767 683
1898	328 436	1932	862 059
1899	405 135	1933	813 629
1900	101 004	1935	1 766 829
1901	129 747	1936	1 561 608
1902	25 424	1937	1 321 633
1903	301 876	1938	668 707
1904	823 979	1961	1 942 333
1906	254 417	1962	1 147 667
1921	2 469 536	1970	1 571 551
1922	1 445 905	1971	1 334 396
1923	1 321 201	1972	905 349
1924	1 118 325	1973	1 777 006
1925	1 563 051	1974	2 249 253
1926	1 129 072	1975	2 219 083
1927	3 261 356	1976	4 670 268
1928	2 271 104	1977	2 303 140
1929	1 583 439	1978	2 393 928
1930	1 218 520		

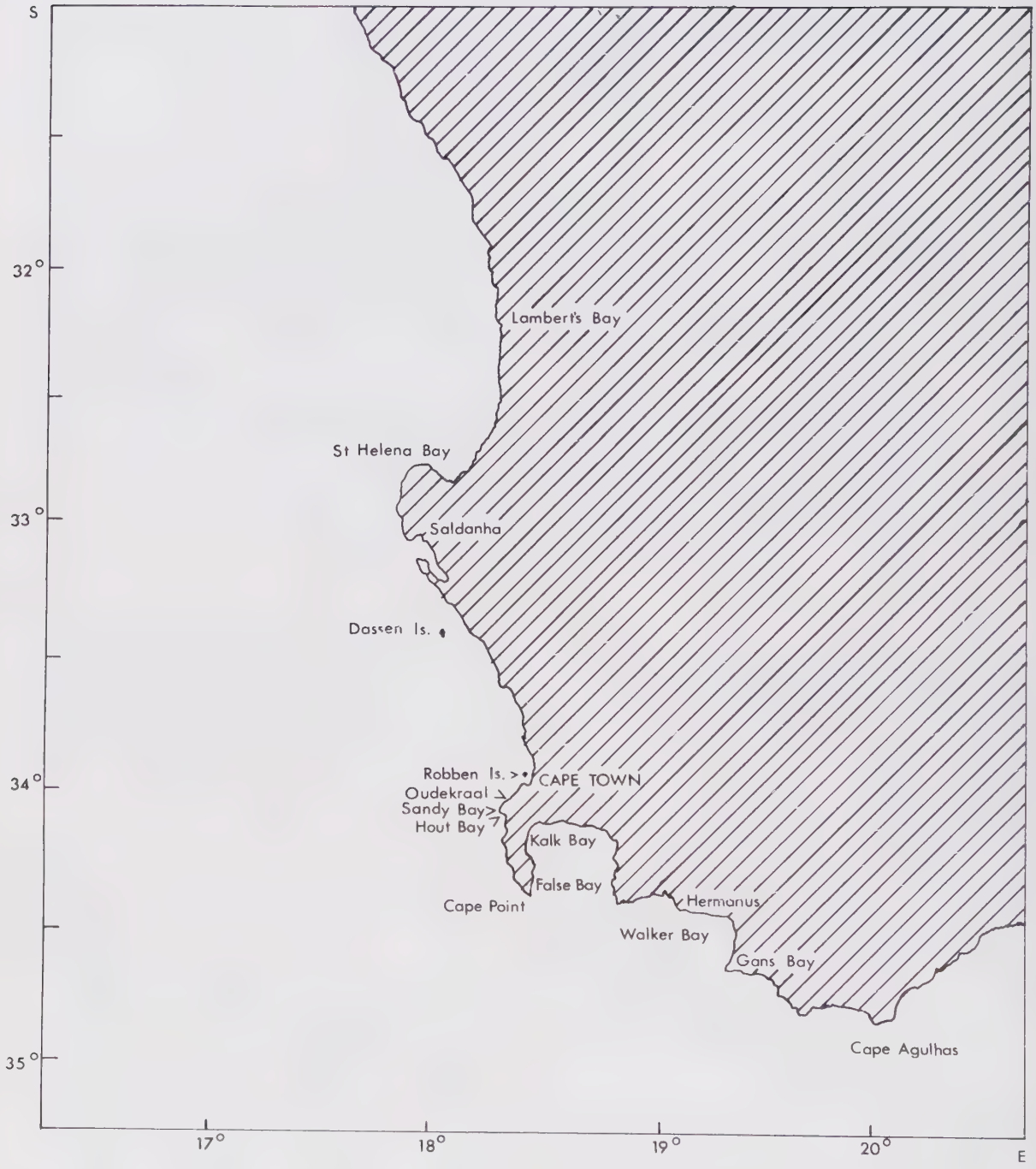

Fig. 1: Sampling ports and localities of tag recoveries

Most of the snoek examined were caught by line from research vessels off the Cape Peninsula (Fig. 1). A few trawled samples were also examined.

TRENDS IN THE LINE FISHERY FOR SNOEK

At the beginning of the century, snoek were caught as far east as Plettenberg Bay (23°30′E), but the overall catch was much smaller because there were fewer fishermen with less efficient boats and gear and a smaller market. The power-driven boats of today can reach the fishing areas quicker and can move more easily from one fishing locality to another. Also, with improved road transport, boats can easily be conveyed from one area to another where snoek are more plentiful. Distribution of the catch to the markets is also facilitated.

Available landing figures indicate that, traditionally, most snoek were caught west of Cape Point, but during 1975 and 1976 there was a change in this tendency and more snoek were caught on the South-East Coast. According to landing figures for the years 1897-1904, 94 per cent of the snoek were caught west of Cape Point. During the eleven years between 1921 and 1931, for which detailed figures of landings are also available, the annual landings of snoek west of Cape Point varied between 63 and 95 per cent of the total, with an average of 78 per cent.

Only six per cent of the annual landings in the years 1970-1972 were made east of Cape Point and in 1973, only ten per cent. Thereafter, the portion of snoek caught annually east of Cape Point gradually increased. In 1974, 39 per cent were caught in the east, in 1975 and 1976, 55 per cent and in 1977, 45 per cent. Only in 1978 did the East Coast catch decline significantly, 19 per cent being caught east of Cape Point. It seems, therefore, that there are overall signs that snoek are becoming more available on the eastward side of their range. This could, however, have resulted from the increased presence of their main food, pilchard and anchovy, in the area during recent years.

The abundance of snoek was deduced from the daily tally at each of the fishing harbours and from the number of boats operating on that day. In general, the boats undertake daily fishing trips and it was decided to base calculations of catch per unit effort (C.P.U.E.) on the catch per boat-day at selected localities. Although it is realized that this measure of abundance is not entirely satisfactory because it does not take into consideration factors such as the varying sizes of the boats, the number of fishermen on board and the number of lines used, it is the only practical method available at present. The total number of boats off-loading snoek at all localities can not be used to obtain a realistic indication of overall abundance because of the differences in size of boats at the different harbours. Snoek are caught from two-man dinghies and from larger boats with 15-20 fishermen on board, and there would thus be a great variation in unit effort. If, for instance, snoek were plentiful during a season in an area where small dinghies were predominantly used (e.g. Lambert's Bay), more small boats (small units) would be operating than in other seasons when snoek were not so plentiful in that area. This greater participation of small boats would then decrease the overall average catch per boat-day if all data were to be combined. It is nevertheless regarded to be indicative of abundance if the information from the different landing places is viewed separately, because the composition of the fleet operating from a particular harbour remains fairly constant from year to year.

Three localities, Kalk Bay, Hout Bay and Lambert's Bay (see Fig. 1) were selected in an effort to determine the abundance of snoek in certain regions. These harbours are sufficiently far apart to ensure that the areas fished from them do not normally overlap. Figure 2 shows the annual catch per unit effort and the total annual catch (1970-1978) at these three localities. In each instance, the total catch displays a similar trend to that of the catch per boat-day. Therefore, it is concluded that at present the fishing effort closely follows abundance. Under these circumstances, the catch curve would appear to be a reliable indication of abundance.

At Kalk Bay, there was a fall in C.P.U.E. from 1970 to 1972 followed by a steady increase until 1977. The increase was especially pronounced in 1974. In 1978, a substantial decline was again evident.

Although there was a steady increase in effort at Hout Bay from 1970 to 1973, the catch per unit effort was inconsistent — high one year and low the next. The highest catch per unit effort was noted in 1976 when snoek were plentiful everywhere. The high C.P.U.E. in 1978 coincided with exceptional concentrations of the fish from Hout Bay to Saldanha, the area fished by the Hout Bay fleet. In 1972, the low C.P.U.E. resulted from the overall scarcity of snoek that year. The sharp decrease in

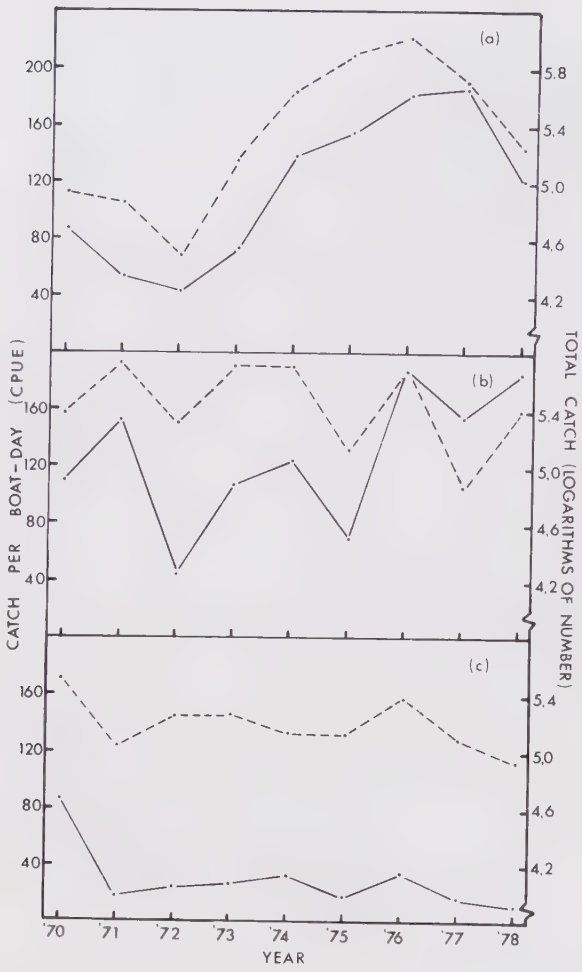

Fig. 2: The annual catch (broken line) and catch per unit effort (solid line) of snoek at (a) Kalk Bay, (b) Hout Bay and (c) Lambert's Bay

1975 coincided with the first year that the greater portion of the total catch was caught east of Cape Point and the trend was confirmed at most harbours on the West Coast.

After a sharp decrease between 1970 and 1971, the C.P.U.E. at Lambert's Bay remained fairly constant, increasing slowly up to 1976, with the sole exception of 1975. During 1977 and 1978, there was a marked decrease in both C.P.U.E. and catch.

It is interesting to note that, while the C.P.U.E. was at its lowest in the northern and most eastern regions during 1971, it was high at Hout Bay, indicating that the main concentration of snoek shoals was on the west coast of the Cape Peninsula.

According to Figure 2, there was an increase in annual availability after the poor 1972 season. The increase was small but steady out of Lambert's Bay, but much faster (except for 1975) in the Hout Bay area and east of Cape Point (Kalk Bay). This shift to the south does not appear to have been completely at the expense of the fishing in the north. In evaluating trends in abundance, fluctuations in size composition should, however, be borne in mind (see section on size composition).

TAG RECOVERY

During 1973 and 1974, a total of 3 139 snoek was tagged of which 18 (0,6 per cent) were recaptured. Table II gives full details of tag recoveries. Although the recovery rate was higher than that found by De Jager (1955) in South West African waters, the 18 tags recovered during this study did not show any long-distance migrations as evinced by snoek marked off South West Africa. The recaptured, tagged snoek indicated only local and random movement. For instance, snoek marked close to Cape Town in May 1974 were recaptured two months later at localities between St Helena Bay and Gans Bay, and snoek tagged in False Bay in July 1974 were recovered at various places between Gans Bay and Saldanha.

SIZE COMPOSITION

Snoek examined during this study were caught by research vessels off the Cape Peninsula, most of them between Cape Town and Hout Bay, in the same manner and at the same localities as those caught by professional fishermen. Regular experimental sampling ceased in 1975, so no data are available for the years 1976-1978. The size composition of the experimental and commercial catches is confidently assumed to be the same. The sampling programme also gives a reasonable indication of overall trends in the variations in size, because a certain amount of intermingling does take place between snoek from different areas (see section on tag recovery).

Because the snoek were caught with hooks that

Table II: Snoek tagging and recovery details

Tag number	Tagging		Recovery		Time elapsed (days)
	Date	Place	Date	Place	
0056	16/5/73	Hout Bay	10/8/73	Sandy Bay	88
1006	7/8/73	Cape Point	15/12/73	False Bay	130
1247	14/8/73	Cape Point	22/12/73	Cape Point	130
0536	17/5/73	Hout Bay	28/5/74	Sandy Bay	377
1383	16/5/74	Oudekraal	6/7/74	St Helena Bay	51
1337	16/5/74	Oudekraal	7/7/74	False Bay	42
1205	14/8/73	Cape Point	11/7/74	Saldanha	331
2055	3/7/74	False Bay	13/7/74	False Bay	10
1263	14/5/74	Robben Island	13/7/74	False Bay	60
1715	23/5/74	Oudekraal	14/7/74	Gans Bay	52
1439	16/5/74	Oudekraal	16/7/74	Hout Bay	61
2180	3/7/74	False Bay	25/7/74	False Bay	22
2033	2/7/74	False Bay	26/7/74	Hermanus	24
1023	7/8/73	Cape Point	27/7/74	Gans Bay	354
1442	16/5/74	Oudekraal	2/1/75	Robben Island	231
2983	12/7/74	Hout Bay	12/5/75	Sandy Bay	304
2123	3/7/74	False Bay	14/5/75	Saldanha	315
2298	3/7/74	False Bay	16/5/75	Hout Bay	317

were selective in not being able to catch the smaller fish, none were caught with a fork length of less than 52 cm. The fork lengths of males ranged from 62 cm to 106 cm and their weights (masses) between 1 120 g and 6 526 g; females ranged from 52 cm to 113 cm in length and 710 g to 6 924 g in weight. Although very large individuals were not encountered during this study, a few snoek weighing up to 9 kg were caught by commercial fishermen at the same time.

Table III: Mean lengths of snoek in experimental catches

Year	Mean fork length (cm)			Number utilized
	Males	Females	Both sexes	
1958	91,0	91,5	91,3	300
1959	86,5	86,9	86,7	84
1960	85,7	87,8	87,2	78
1961	82,2	84,5	83,4	310
1962	85,7	88,6	87,5	78
1963	80,1	81,6	80,8	189
1964	No available data			
1965	89,1	90,9	90,4	145
1966	89,1	91,1	90,4	188
1967	86,3	88,2	87,4	206
1968	85,5	89,9	88,8	181
1969	83,3	85,7	84,6	109
1970	77,7	82,4	80,7	636
1971	80,8	86,1	85,1	174
1972	83,0	87,4	85,7	232
1973	80,8	85,8	84,2	150
1974	82,8	83,1	83,1	251
1975	80,0	83,3	82,6	206

From 1959 to 1963, 2,6-18 per cent of the annual experimental catches consisted of large snoek over 95 cm long, but from 1965 to 1968 the large individuals were much more in evidence and comprised 26-36 per cent of the yearly catches. From 1969 to 1975, large snoek were caught in ever decreasing numbers.

Although Table III, which depicts the mean length frequencies (fork lengths) for each year from 1958 to 1975 for males and females separately as well as for both sexes combined, shows an occasional slight increase in mean length over two successive years, the general trend is a small but steady decline in the mean length of the snoek caught. This decrease in both mean length of the population and availability of large fish indicates that the snoek stocks are affected by exploitation. However, it does not necessarily mean that overfishing is taking place, because the general trends in the fishery are for increasing annual catches and catch per unit effort.

From Table III, it is also evident that, for each year, the mean length of the females was slightly greater than that of the males.

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship was computed for males and females separately and for the sexes

combined. Data were obtained from 2 891 snoek during different months between 1958 and 1975. The equation $W = aL^n$ was applied, where W is the round weight in grammes, L the fork length in centimetres, a the constant and n the exponent. The regression equations are given in Table IV.

Table IV: Length-weight relationships of the snoek

Sex	Length-weight relationship	Correlation coefficient
Male	$W = 0{,}0178\ L^{2{,}7196}$	0,9026
Female	$W = 0{,}0094\ L^{2{,}8754}$	0,9311
Male + Female	$W = 0{,}0204\ L^{2{,}6940}$	0,8136

When the length-weight relationship of the South African snoek is compared with those of the barracouta from New Zealand and the Australian snoek from South Victoria, it is found that the South African snoek is heavier per unit length than either of the other two (Mehl 1971, Blackburn 1960). The three relationships, determined by the method of least squares, are presented graphically for comparison in Figure 3.

The large differences in length-weight relationship could be the result of a difference in diet. Prakash and Milne (1958) showed that the growth rate and final size of the coho salmon is much greater if its diet of crustaceans is supplemented by fish. Fields (1965) suggests that the variations in size of individual spawning squid *Loligo opalescens* in Monterey Bay might be caused by changes in diet; the squid were larger during the years when fish (pilchard and anchovy) were plentiful and smaller when fish were scarcer. According to Blackburn (1957) and Mehl (1969), the main food of the Australian snoek and the New Zealand barracouta consists of euphausiids whereas the South African snoek feeds mainly on teleosts, predominantly pilchard and anchovy (Nepgen 1979).

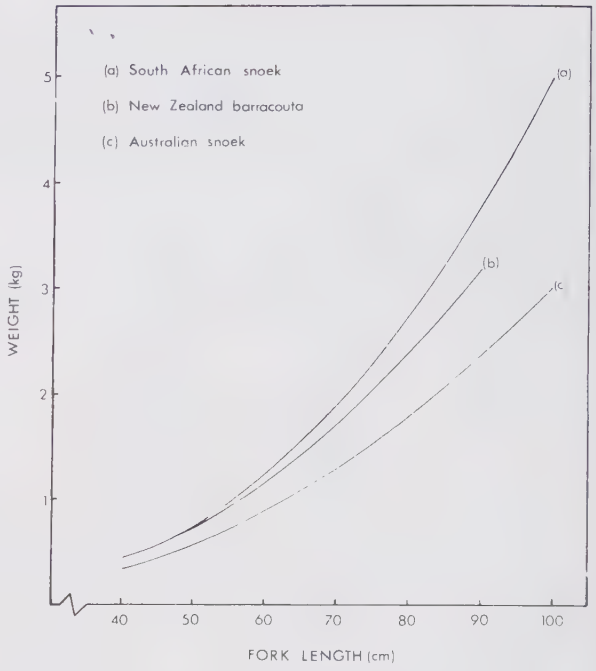

Fig. 3: Comparison of length-weight relationship of South African snoek with those of Australian snoek and New Zealand barracouta

CONDITION

Snoek exhibit considerable seasonal variation in condition during a year. Most fish are in prime condition from February to June, but during July their condition starts declining markedly, and those caught from August to November are usually in a poor condition and of inferior quality with little fat. According to Van Wyk (1944), fish caught between August and November are usually low in body oil and protein but the percentage moisture content is high. During these months, which also coincide with the closed season for the catching of snoek in the Cape, the fish can usually be caught east of Cape Point on hand lines and they are abundant in bottom trawl catches on the Agulhas Bank. During December, snoek in a better and fatter condition, with small inactive gonads, begin to appear in increasing numbers amongst those in poor condition.

Changes in the condition factor *(K)* of a fish may be described by the equation $K = \frac{w}{L^n}$, where w is the weight of the fish, L is the length and n is the exponent. For an ideal fish which maintains the same shape, the exponent would be 3, but this rarely holds true because most species do change their shape as they grow (Le Gren 1951).

The value of the exponent n for snoek was found empirically to be 2,694 according to length-weight

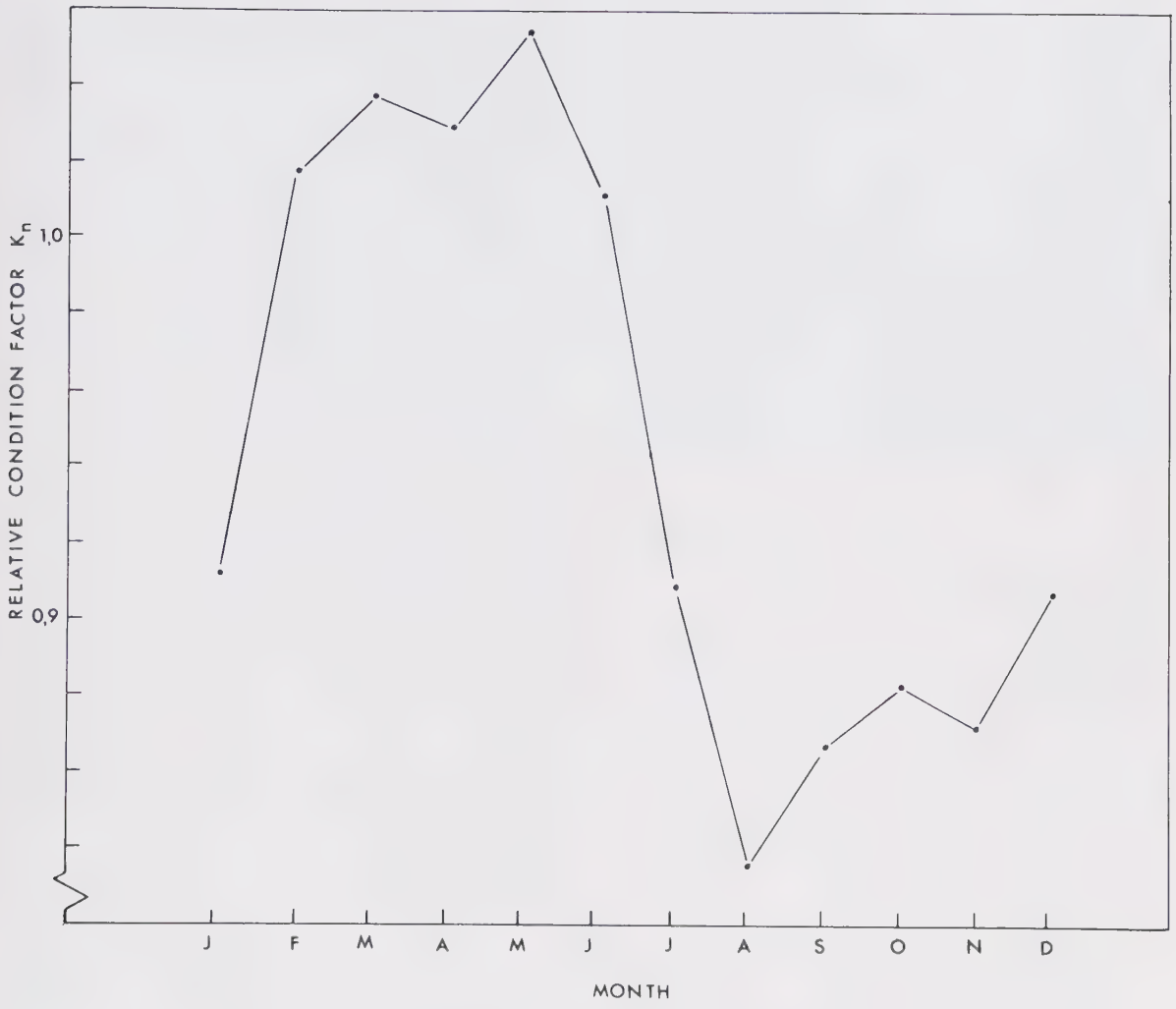

Fig. 4: Mean monthly relative condition factor, 1958-1974

determination (Table IV). This is low but not as low as the value of 2,36 calculated by Blackburn (1960) for the Australian snoek or as the value of 2,42 calculated by Mehl (1971) for the New Zealand barracouta.

The relative condition factor K_n was thought to be more meaningful and was determined by dividing the observed weight (w) by the weight calculated from the length-weight equation (W), i.e. $K_n = \frac{w}{W}$ (Le Gren 1951). The relative condition factor eliminates the effect of length, because it describes the variation in weight not associated with length.

The mean monthly values of K_n, compiled from data collected off the Cape Peninsula over a number of years, reflect the drastic changes in condition during the year (Fig. 4). In March, April and May (autumn), snoek reach their prime condition and attain a high mean relative condition factor. After the peak in May, condition starts to deteriorate slowly in June and then rapidly during July, and the

minimum value of K_n is reached in August. Thereafter, condition starts to improve slowly. According to Hart (1946), most fish species in temperate waters reach their peak of condition just prior to spawning.

Examination of snoek gonads shows that the majority of gonads are small and in the resting stage at the beginning of the year, but that from April onwards, the gonads start to enlarge and reach a relatively advanced stage of development during June and July. From July onwards, females with ripe and ripe-and-running ovaries are caught as spawning gathers momentum and more and more snoek are found with gonads in the spent condition, indicating that the main spawning season has commenced (Sea Fisheries Branch, unpublished data). Snoek apparently start spawning about two months after reaching their prime condition. The deterioration in condition therefore coincides with the beginning of the main spawning season and with the associated increased metabolic strain of spawning.

Results obtained by Van Wyk (1944), in determining the oil content of the edible portions, and by Rapson *et al.* (1944), in an analysis of the liver, intestinal and head oils of the snoek, indicate seasonal fluctuations in oil content in the different parts of the snoek similar to the seasonal changes in the mean relative condition factor. Oil content was high in autumn but low in late winter and early spring.

No correlation could be found between the feeding habits of the snoek and the cycle of K_n as found by Mehl (1971) for the New Zealand barracouta.

It seems, therefore, that the seasonal changes in condition of the snoek are a result of changes in the body of the snoek caused by a build-up for

Table V: Monthly calculated weight (kg) per 1-cm fork length

Length (cm)	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
70	1,7	1,9	2,0	2,0	2,0	1,9	1,7	1,6	1,7	1,7	1,7	1,7
71	1,8	2,0	2,1	2,0	2,1	2,0	1,8	1,7	1,7	1,8	1,7	1,8
72	1,9	2,1	2,1	2,1	2,2	2,1	1,9	1,7	1,8	1,8	1,8	1,9
73	1,9	2,2	2,2	2,2	2,3	2,2	1,9	1,8	1,9	1,9	1,9	1,9
74	2,0	2,3	2,3	2,3	2,3	2,2	2,0	1,9	1,9	2,0	1,9	2,0
75	2,1	2,3	2,4	2,4	2,4	2,3	2,1	1,9	2,0	2,0	2,0	2,1
76	2,2	2,4	2,5	2,4	2,5	2,4	2,2	2,0	2,1	2,1	2,1	2,2
77	2,3	2,5	2,6	2,5	2,6	2,5	2,2	2,1	2,1	2,2	2,2	2,3
78	2,3	2,6	2,6	2,6	2,7	2,6	2,3	2,1	2,2	2,3	2,2	2,4
79	2,4	2,7	2,7	2,7	2,8	2,7	2,4	2,2	2,3	2,3	2,3	2,4
80	2,5	2,8	2,8	2,8	2,9	2,8	2,5	2,3	2,4	2,4	2,4	2,5
81	2,6	2,9	2,9	2,9	3,0	2,9	2,6	2,4	2,4	2,5	2,5	2,6
82	2,7	3,0	3,0	3,0	3,1	3,0	2,7	2,4	2,5	2,6	2,5	2,7
83	2,8	3,1	3,1	3,1	3,2	3,1	2,7	2,5	2,6	2,7	2,6	2,7
84	2,9	3,2	3,2	3,2	3,3	3,2	2,8	2,6	2,7	2,7	2,7	2,8
85	2,9	3,3	3,3	3,3	3,4	3,3	2,9	2,7	2,8	2,8	2,8	2,9
86	3,0	3,4	3,4	3,4	3,5	3,4	3,0	2,8	2,9	2,9	2,9	3,0
87	3,1	3,5	3,6	3,5	3,6	3,5	3,1	2,9	3,0	3,0	3,0	3,1
88	3,2	3,6	3,7	3,6	3,7	3,6	3,2	3,0	3,1	3,1	3,1	3,2
89	3,3	3,7	3,8	3,7	3,8	3,7	3,3	3,0	3,2	3,2	3,2	3,3
90	3,4	3,8	3,9	3,9	4,0	3,8	3,4	3,1	3,3	3,3	3,3	3,4
91	3,5	3,9	4,0	3,9	4,1	3,9	3,5	3,2	3,4	3,4	3,4	3,5
92	3,6	4,1	4,1	4,0	4,2	4,0	3,6	3,3	3,5	3,5	3,5	3,6
93	3,7	4,2	4,3	4,1	4,3	4,1	3,7	3,4	3,6	3,6	3,6	3,7
94	3,9	4,3	4,4	4,3	4,5	4,3	3,8	3,5	3,7	3,7	3,7	3,8
95	4,0	4,4	4,5	4,5	4,6	4,4	3,9	3,6	3,8	3,8	3,8	3,9
96	4,1	4,5	4,6	4,5	4,7	4,5	4,1	3,7	3,9	3,9	3,9	4,1
97	4,2	4,7	4,8	4,6	4,8	4,6	4,2	3,8	4,0	4,0	4,0	4,2
98	4,3	4,8	4,9	4,8	5,0	4,8	4,3	3,9	4,1	4,1	4,1	4,3
99	4,4	4,9	5,0	5,0	5,1	4,9	4,4	4,1	4,2	4,3	4,2	4,4
100	4,6	5,1	5,2	5,1	5,3	5,0	4,5	4,2	4,3	4,4	4,4	4,5
101	4,7	5,2	5,3	5,3	5,4	5,2	4,6	4,3	4,4	4,5	4,5	4,6
102	4,8	5,4	5,5	5,4	5,6	5,3	4,8	4,4	4,6	4,6	4,6	4,8
103	4,9	5,5	5,6	5,5	5,7	5,5	4,9	4,5	4,7	4,8	4,7	4,9
104	5,1	5,6	5,7	5,7	5,9	5,6	5,1	4,6	4,8	4,9	4,8	5,0
105	5,2	5,8	5,9	5,8	6,0	5,7	5,2	4,8	4,9	5,0	5,0	5,2

Table VI: Results of verification of theoretical weight at length

Sample	Sampling date	Locality	Number of snoek	Mean fork length (cm)	Mean actual weight (kg)	Mean estimated weight (kg)	Error (%)
1	25/5/67	St Helena Bay	10	97	4,717	4,8	+1,8
2	8/4/70	St Helena Bay	20	73	2,054	2,2	+7,1
3	18/5/72	Hout Bay	10	92	4,244	4,2	−1,0
4	19/5/72	Hout Bay	20	88	3,676	3,7	+0,7
5	16/6/72	Hout Bay	10	88	3,485	3,6	+3,3
6	15/5/73	Hout Bay	20	85	3,355	3,4	+1,3
7	9/7/74	Hout Bay	20	82	2,681	2,7	+0,7
8	18/8/75	Cape Point	20	83	2,424	2,5	+3,1
9	19/7/77	Cape Point	20	83	2,640	2,7	+2,3
10	2/8/77	West Coast trawl	10	76	1,989	2,0	+0,6

spawning and the associated metabolic strain.

The length-weight relationship and the mean relative condition factor for each month have been used to compile a list of the theoretical monthly weights of snoek at each centimetre length (Table V). The theoretical weights were found to be very close to the actual weights, but because weights of individual snoek at a particular length vary considerably, Table V should only be regarded as reliable when samples consist of at least 10 fish.

The reliability of Table V was tested by comparing actual weights of ten samples, four consisting of 10 fish each and six of 20 fish each, of which the actual weights and lengths were known. The results are summarized in Table VI. The error varied between −1,0 per cent and +7,1 per cent and is considered small. Most of the mean estimated weights were found to be slightly higher than the mean actual weights.

The approximate weight of a sample of known mean length can therefore be calculated for use in the field, e.g. at sea where it is sometimes impossible to get the actual weights but the lengths can easily be obtained. The values in Table V were derived from information collected over a number of years and spread throughout each month. Thus, errors resulting from abnormal seasons and from deviation of the day of catching from the middle of the month should be regarded as minimal.

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LITERATURE CITED

BLACKBURN, M. 1957 — The relation between the food of the Australian barracouta, *Thyrsites atun* (Euphrasen), and recent fluctuations in the fisheries. *Aust. J. mar. Freshw. Res.* **8**(1):29-54.

BLACKBURN, M. 1960 — A study of condition (weight for length) of Australian barracouta, *Thyrsites atun* (Euphrasen). *Aust. J. mar. Freshw. Res.* **11**(1):14-41.

DE JAGER, B. VAN D. 1955 — The South African pilchard (*Sardinops ocellata*) — The development of the snoek (*Thyrsites atun*) a fish predator of the pilchard. *Invest'l Rep. Div. Fish. S. Afr.* **19**:16 pp.

FIELDS, W. G. 1965 — The structure, development, food relations, reproduction, and life history of the squid *Loligo opalescens* Berry. *Fish Bull. Calif.* **131**:108 pp.

HART, T. J. 1946 — Report on trawling surveys on the Patagonian continental shelf. *"Discovery" Rep.* **23**:223-408.

LE GREN, E. D. 1951 — The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.* **20**(2):201-219.

MEHL, J. A. P. 1969 — Food of barracouta (Teleost[e]i: Gempylidae) in eastern Cook Strait. *N.Z. J. mar. Freshw. Res.* **3**(3):389-394.

MEHL, J. A. P. 1971 — Spawning and length-weight of barracouta (Teleostei:Gempylidae) from eastern Cook Strait. *N.Z. J. mar. Freshw. Res.* **5**(2):300-317.

NEPGEN, C. S. de V. 1979 — The food of the snoek *Thyrsites atun*. *Fish. Bull. S. Afr.* **11**:39-42.

PRAKASH, A. and D. J. MILNE 1958 — Food as a factor affecting the growth of coho salmon off the east and west coast of Vancouver Island, B.C. *Prog. Rep. Pacif. Cst Stns* **112**:7-9.

RAPSON, W. S., SCHWARTZ, H. M., MOLTENO C. J. and N. J. VAN RENSBURG 1944 — South African fish products. 4. The snoek (*Thyrsites atun*, Euphr.). *J. Soc. chem. Ind., Lond.* **63**:21-23.

VAN WYK, G. F. 1944 — South African fish products. 8. Composition of the flesh of Cape fishes. *J. Soc. chem. Ind., Lond.* **63**:367-371.

Fish. Bull. S. Afr. 12:44—48
1979

CHANGES IN ABUNDANCE OF ALBACORE *THUNNUS ALALUNGA* AND YELLOWFIN *T. ALBACARES* OFF SOUTHERN AFRICA, 1969-1976

S. R. DA FONSECA BAPTISTA

Catches of albacore and yellowfin tuna made by Japanese longline boats off southern Africa from 1969 to 1976 are analysed. Hooking rates show an increase in abundance of yellowfin but a decrease in that of albacore. Effort increased and shifted from the coastal region to off-shore waters. It is suggested that this increase in effort caused the reduction in abundance of albacore, while the shifting of effort away from the coastal regions contributed to the increase in abundance of yellowfin tuna in inshore waters.

Vangste van langvin- en geelvintuna, wat deur Japanese langlynbote vanaf 1969 tot 1976 langs die Suider-Afrikaanse kus gemaak is, is ontleed. Die vangskoers toon 'n toename in die talrykheid van geelvin aan terwyl dié van langvin afgeneem het. Vangspoging het toegeneem en van die aanlandige na die aflandige gebiede verskuif. Daar word aan die hand gedoen dat toename in poging die afname in talrykheid van langvin veroorsaak het terwyl die verskuiwing van poging weg van die aanlandige gebiede bygedra het tot die toename in talrykheid van geelvintuna in kuswaters.

Off the southern coast of Africa, the tuna fishery is conducted by Japanese and Taiwanese longline boats and also, to a small extent, by South African sport boats fishing close inshore. Albacore *Thunnus alalunga* and yellowfin *T. albacares* are the principal target species.

The aim of this report is to analyse the state of the fishery within the area bounded by latitudes 25°S and 50°S and by longitudes 5°E and 40°E (Fig. 1), and to establish whether changes in availability of both species are interrelated. Information from the Taiwanese longline and South African sport fisheries is not available. Thus, only Japanese data are used (Fisheries Agency of Japan, 1969 to 1976).

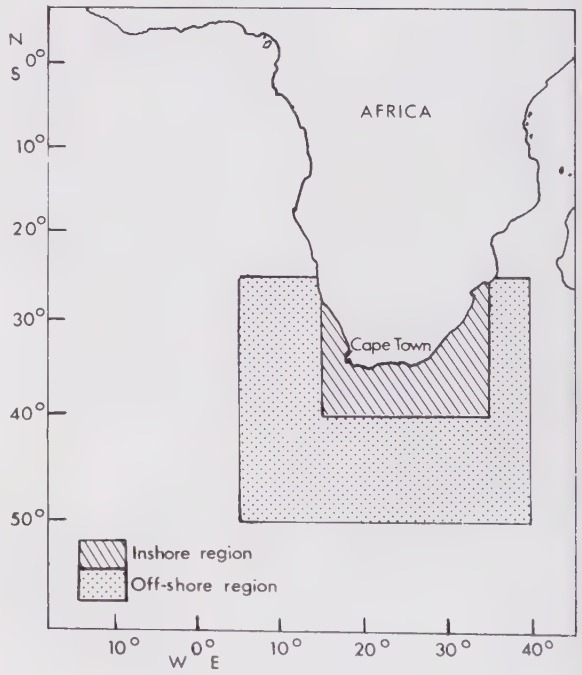

Fig. 1: Tuna fishing area off southern Africa covered in this report

CHANGES IN ABUNDANCE OF TUNA SPECIES

In southern African waters, albacore landings have decreased as major effort has shifted to the off-shore areas, whereas landings of yellowfin, although irregular, appear to have improved (Table I).

Changes in the abundance of various tuna species have been recorded in several fishing areas of the world and different theories have been put forward. In a study of the changes in availability of albacore in the Eastern Pacific Ocean during 1952 and 1958, Johnson (1963) found that the distribution of the species appears to be influenced by conditions in the ocean and the atmosphere. Uda (1961, cited by Johnson *op. cit.*) reported a reciprocal relationship between the catches in the western and the eastern Pacific Ocean and explained it by trends in sea temperature. Lima and Wise (1963) stated that, in the western tropical Atlantic, the yellowfin tuna show a better defined seasonal distribution than

Table I: Landings of albacore and yellowfin tuna and effort used by Japanese longliners

Year	Albacore		Yellowfin	
	Effort (number of hooks × 10^3)	Catch (number of fish)	Effort (number of hooks × 10^3)	Catch (number of fish)
1969	20 545	298 881	8 011	24 940
1970	12 816	138 748	3 804	12 141
1971	13 483	179 400	3 235	16 635
1972	22 372	103 662	5 055	43 971
1973	31 150	92 466	4 438	17 029
1974	31 195	74 586	6 656	36 236
1975	19 403	36 627	3 970	73 939
1976	20 133	61 905	3 210	25 118

albacore, resulting in greater seasonal fluctuation in catches. The abundance of the two principal species in the Angolan tuna catches was estimated by De Campos Rosado (1971), who found a progressive replacement of yellowfin by skipjack *Katsuwonus pelamis* during the period 1956-1969. He also stated that this change in abundance suggested competition between the two species where skipjack had an advantage over yellowfin, probably owing to a larger coefficient of natural increase or to adaptability to a wider range of ecological conditions. Similar changes in abundance of yellowfin were observed by Champagnat (1968) off Dakar between the years 1955 and 1967, and Le Guen and Wise (1967) reported that the decrease in abundance of yellowfin and its progressive replacement by skipjack after 1956 coincided with an increase in effort by Japanese longliners in the eastern tropical Atlantic. However, catch statistics indicate that yellowfin apparently increased in abundance off Pointe-Noire (a neighbouring area of Angola and Dakar) between 1964 and 1967 (Le Guen *et al.* 1968).

According to Wise and Fox (1969), fishing effort in the whole Atlantic reached, by 1965, a level higher than yellowfin stocks could support, and the species could have been reduced from one of major importance to one constituting little more than an incidental catch if catch rates were to continue to decrease. In a study of the Japanese tuna fishery off South Africa between 1964 and 1967, Nepgen (1970) stated that, while the catch rates for yellowfin steadily declined, the percentage of longfin tuna (albacore) in the catch increased slightly in the western region and remained more or less constant in the east.

STATISTICAL AREAS OFF SOUTHERN AFRICA

Japanese data on catch and effort are given by 5° × 5° sub-areas and, because yellowfin tuna appears to be a species which is caught more often near the coast, the sub-areas are here grouped together into two large regions, namely inshore and off shore (Fig. 1). Table II gives the percentage of the effort used and the catch made in both regions.

Table II: Percentages of effort and catch by Japanese tuna longliners off southern Africa, 1969-1976

	Regions off southern Africa	
	Inshore	Off shore
Effort	23,3	76,7
Catch		
Albacore	30,5	69,5
Yellowfin	94,8	5,2

The percentage of the total effort of Japanese boats employed within the inshore region has steadily decreased from 39,0 per cent in 1969 to 15,9 per cent in 1976. This decrease in effort becomes more significant if it is considered that, as recently as 1967, 51,6 per cent of the Japanese effort in the whole area was in the inshore region.

The inshore region comprises just over 20 per cent of the area being studied, and the effort expended in recent years in comparison to the total effort is of the same order (Table II). The catches of albacore are apparently uniformly distributed through both regions, but yellowfin catches, 94,8 per cent of which were made close to the coast, indicate that the species is an inshore one. Therefore, in this study, the yellowfin data used refer only to the inshore region, but albacore information to the whole area off southern Africa (Fig. 1).

JAPANESE TUNA FISHERY OFF SOUTHERN AFRICA

The annual effort used by the Japanese boats working off southern Africa followed a similar

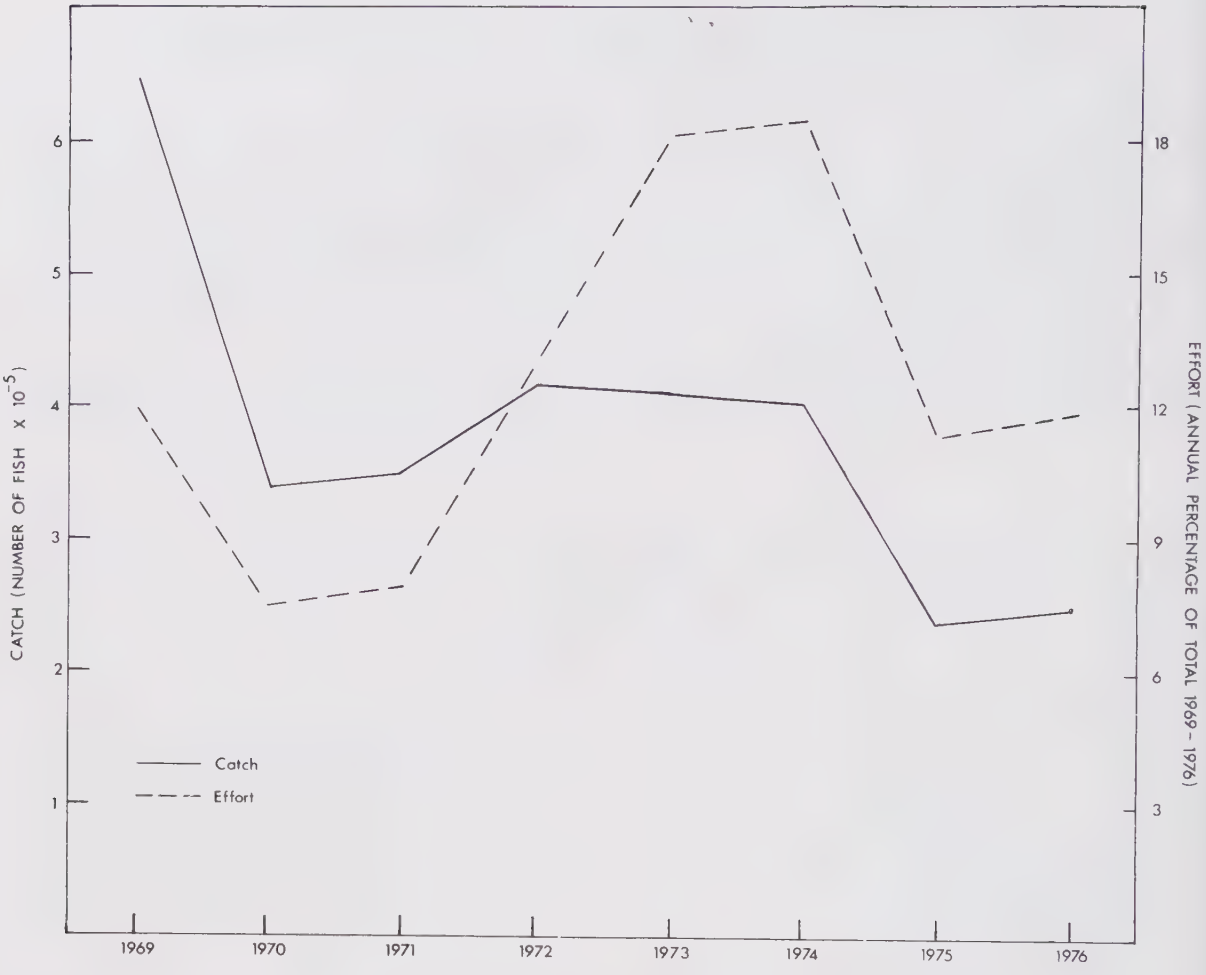

Fig. 2: Annual catch and effort of the Japanese tuna longline fishery (all species) off southern Africa, 1969-1976

pattern to that of the catches (Fig. 2), which suggests that the effect on the combined tuna stocks during the study period may not have been great.

However, analysis of catch rates of individual species indicates a decline in abundance of albacore (Fig. 3). Yellowfin and albacore do not have the same fishing grounds off southern Africa and the decline in abundance of albacore can not, therefore, be attributed to competition between the two species. Albacore is caught predominantly outside the South African 200-mile fishing zone, mainly on the West Coast but also to a lesser extent further east. Most yellowfin is caught in inshore waters off the East Coast (Fig. 4).

Because albacore is one of the principal target species for the Japanese fishery, the decline in its abundance could well be due to overfishing. This is consistent with the findings of Shiohama (1977), who reported that the albacore catch had almost reached the level of the maximum sustainable yield

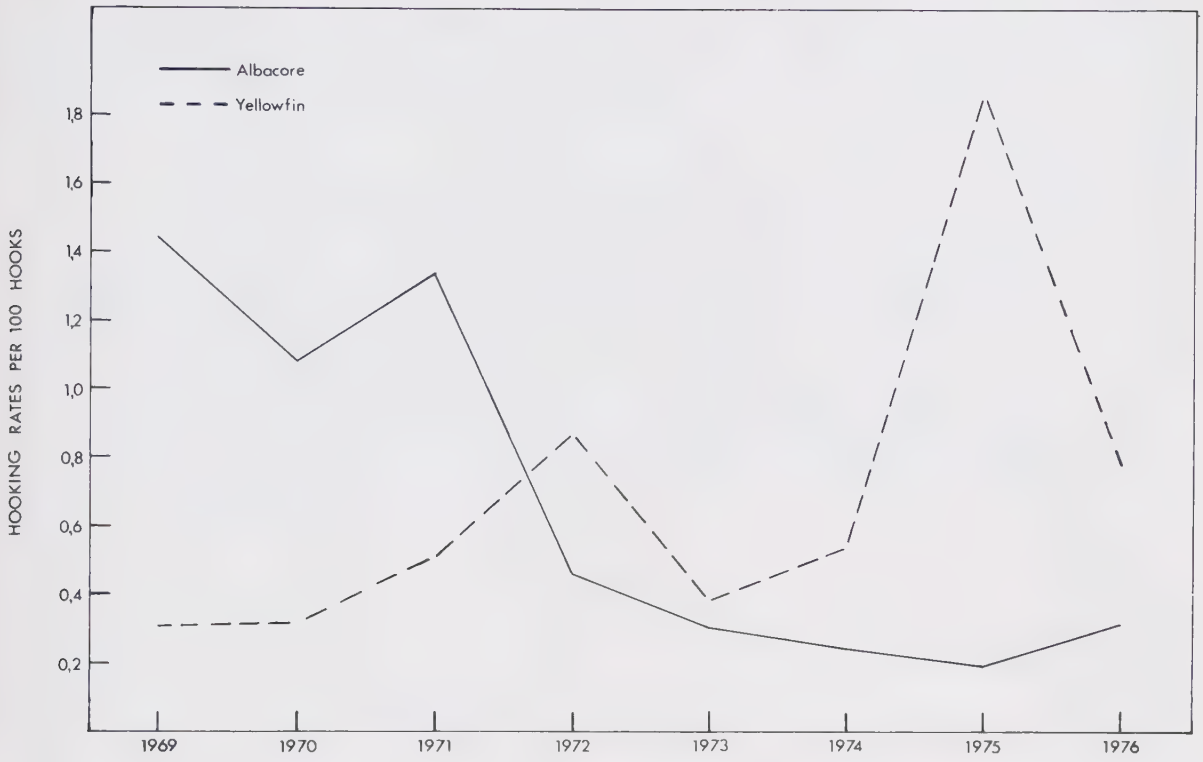

Fig. 3: Hooking rates for albacore and yellowfin caught off southern Africa by Japanese longliners, 1969-1976

for the southern Atlantic stock. In the Atlantic Ocean, fishing effort for yellowfin appears to have stabilized or even declined, and results from production-model analyses continue to support the conclusion that the curve relating average sustained catch to fishing effort is flat-topped (ICCAT 1977).

DISCUSSION

The apparent progressive replacement of albacore by yellowfin off southern Africa may have been caused by intensive exploitation of the albacore stocks concurrent with a reduction of fishing effort within the inshore region, which in turn contributed to the increase in abundance of yellowfin. Interaction between the two species, therefore, is not implied.

These results, in terms of the abundance of both species, disagree with the findings of Nepgen (1970), who noted a decline in yellowfin abundance between 1964 and 1967 but an associated general increase in that of albacore during the same years. However, it is suggested that a shifting of effort from the inshore to the off-shore region during the late sixties could have been the cause.

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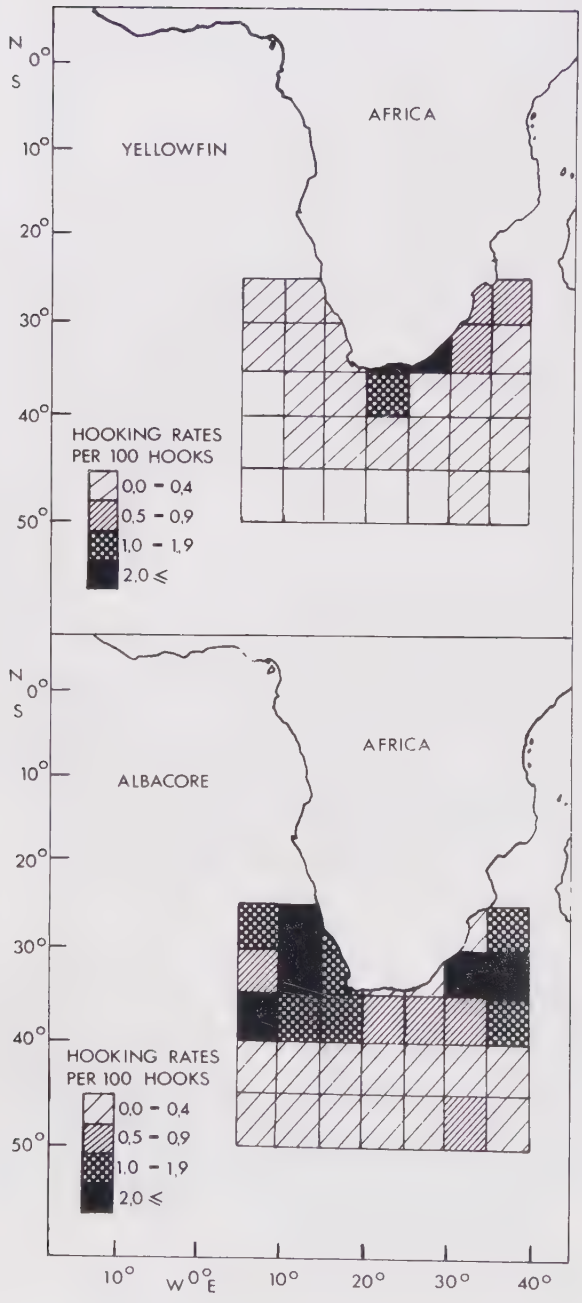

Fig. 4: Main fishing regions for yellowfin and albacore off southern Africa, 1969-1976

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LITERATURE CITED

CHAMPAGNAT, C. 1968 — Les campagnes thonières de "Pêche Fraiche" à Dakar (1955 — 1967). *ORSTOM, Dakar-Thiarove, Dakar.* **015**:53 pp. (mimeo).

DE CAMPOS ROSADO, J. M. 1971 — Long-term changes in abundance of yellowfin and skipjack off the coast of Angola. *J. Cons. perm. int. Explor. Mer* **34**(1):65-75.

FISHERIES AGENCY OF JAPAN 1969 to 1976 — Annual Report of effort and catch statistics by area on Japanese tuna longline fishery.

ICCAT 1977 — Report for biennial period 1976-1977, **1**:69-146.

JOHNSON, J. H. 1963 — Change in availability of albacore in the eastern Pacific Ocean (1952 and 1958). In *Proceedings of the world scientific meeting on the biology of tunas and related species, La Jolla, 1962.* Rosa, H., Jr. (Ed.). *F.A.O. Fish. Rep.* **6**(3):1227-1235.

LE GUEN, J-C. and J. P. WISE 1967 — Méthode nouvelle d'application du modèle de Schaefer aux populations exploitées d' albacores dans l'Atlantique. *Cah. ORSTOM, sér. Océanogr.* **5**(2):79-93.

LE GUEN, J-C., POINSARD, F. and J. GAYDE 1968 — La campagne thonnière 1967 à Pointe-Noire (Congo). *Pêche marit.* **1084**:473-476.

LIMA, F. R. and J. P. WISE 1963 — A first examination of the abundance and distribution of yellowfin and albacore tuna in the western tropical Atlantic, 1957-1961. In *Proceedings of the world scientific meeting on the biology of tunas and related species, La Jolla, 1962.* Rosa, H., Jr. (Ed.). *F.A.O. Fish. Rep.* **6**(3):1515-1521.

NEPGEN, C. S. DE V. 1970 — The Japanese longline fishery off the South African coast, 1964-1967. *Invest. Rep. Div. Sea Fish.* **90**:13 pp.

SHIOHAMA, T. 1977 — Stock assessment of Atlantic albacore by production model analysis. *Collve Vol. Sci. Pap. int. Commn Cons. Atl. Tunas* **6**(2):233-236.

WISE, J. P. and W. W. FOX 1969 — The Japanese Atlantic longline fishery, 1965, and the status of the yellowfin tuna and albacore stocks. *Spec. scient. Rep. U.S. Fish Wildl. Serv.* **582**:7 pp.

Viss.—Bull. S.-Afr. 12:49—52
1979

'N VERBETERDE TEGNIEK VIR DIE BRAND VAN HEEL OTOLIETE

J. D. VENTER

Otoliete word gebruik vir ouderdomsbepaling van marsbanker *Trachurus trachurus capensis* Cast. Die tegniek om otoliete te brand is verbeter om die leesbaarheid van veral die kleiner marsbankerotoliete wat verkieslik heel gelees moet word, te verhoog. Dit is ook suksesvol toegepas op die otoliete van verskeie ander vissoorte. Om otoliete op 'n gewone skeermeslemmetjie of stukkie dun blikplaatjie oor 'n laag brandende brandspiritus- of gasvlam te brand, skakel die probleem uit van onegalige verbranding, van oorverbranding, kraak van otoliete, onnodige hantering van otoliete wat maklik breek en dié van otoliete wat eenvoudig in 'n oop vlam ontplof.

Otoliths are used for the age determination of horse mackerel *Trachurus trachurus capensis* Cast. The technique of burning was improved to better the readability of particularly the otoliths of smaller horse mackerel, which should preferably be read whole. The method was applied successfully to otoliths of several other kinds of fish. Burning otoliths on an ordinary razor-blade or a small piece of thin tinplate over a slow-burning methylated spirit flame or gas flame solves the problems of uneven burning, of overheating, of cracking of otoliths, and of unnecessary handling of fragile otoliths. The shattering of some otoliths when burned in an open flame is also minimized.

In ouderdomstudies oor marsbanker *Trachurus trachurus capensis* Cast. word ongebreekte otoliete gebruik om die ouderdom van vis met 'n liggaamlengte tot 39,5 cm te bepaal, aangesien die otoliet van hierdie grootte vis nog afplat na die rand toe en hierdie metode ook tyd bespaar op die tegniek van Christensen (1964) om otoliete te breek en in Plasticine te monteer. By marsbanker groter as 39,5 cm liggaamslengte lê die jaarringe op die rand van die otoliet baie na aan mekaar en moet die otoliete gebreek word om die jaarringe op die breekvlak te lees. Om laasgenoemde otoliete te breek, word die ongebrande otoliet met 'n tangetjie oor die dwarste van die otoliet, net langs die nukleus aan die rostrumkant, vasgeknyp en die voorste gedeelte van die otoliet dan met die voorvinger en duim van die ander hand afgebreek. 'n Relatief gladde en reguit transversale breekvlak word op hierdie wyse verkry.

Christensen (1964) beskryf 'n metode om die lees van jaarringe in gebreekte otoliete aansienlik te vergemaklik deur die otoliete vooraf te brand, 'n metode wat ook onder andere met goeie gevolg deur May (1965), Blacker (1969), Geldenhuys (1973) en Macer (1977) gebruik is. Met die brand van marsbankerotoliete oor 'n oop vlam word egter probleme ondervind met ongebreekte otoliete wat gelees moet word, naamlik:

(i) Veral die kleiner otoliete kan maklik tot 'n asvaal kleur brand indien hul vir 'n oomblik te lank oor die oop vlam gehou word.
(ii) Baie otoliete kraak sodanig oor 'n oop vlam dat dit ouderdomsbepaling in hoë mate bemoeilik en die otoliete selfs onbruikbaar vir ouderdomsbepaling maak (Fig. 1).
(iii) Onegalige verbranding van die otoliet geskied op die plek waar dit met 'n tangetjie oor die oop vlam vasgehou word.

Bogenoemde probleme met die brand van heel otoliete kan grootliks uitgeskakel word deur die skoongemaakte, droë otoliet tydens die brandproses nie in direkte kontak met die oop vlam te bring nie. 'n Eenvoudige maar doeltreffende metode is gevolg deur die otoliet op 'n gewone skeermeslemmetjie of dun metaalplaatjie te plaas en die lemmetjie dan met 'n tangetjie stadig heen en weer oor 'n laag brandende brandspiritus- of gasvlam te beweeg. Vir marsbanker duur die brandproses byvoorbeeld van 5 tot 15 sekondes, na gelang van die grootte van die otoliet en die temperatuur van die vlam. In die brandproses verander 'n otoliet se kleur agtereenvolgens van wit na geelbruin, dan na bruinswart en spoedig daarna tot swart en asvaal. Tydens die brand van ongebreekte otoliete word die lemmetjie van die vlam verwyder sodra die otoliet 'n geelbruin kleur bereik. Die hitte van die lemmetjie sal verbranding van die otoliet voortsit en sodra die kleur bruinswart is, moet die lemmetjie gekantel word sodat die otoliet afval om oorverbranding te verhoed. Die lemmetjie word naby die oppervlak van die werksbank gekantel sodat die otoliet op 'n stukkie filtreerpapier afval, waar dit

Fig 1 Laterale aansig van gebrande marsbankerotoliete (A) Otoliet gebrand oor n oop vlam vir 6 sekondes, (B) Otoliet gebrand op 'n skeermeslemmetjie vir 13 sekondes

Fig. 2: Laterale aansig van sardynotoliete: (A) Otoliet gebrand op 'n skeermeslemmetjie vir 10 sekondes, (B) Ongebrande otoliet

gelaat word om heeltemal af te koel alvorens dit in 'n bakkie met water of xileen geplaas word om die jaarringe te lees. Indien die warm otoliet direk in die bakkie met vloeistof geplaas word, kraak die otoliet. Gebreekte otoliete kan op dieselfde wyse gebrand word.

Welslae met bogenoemde tegniek is ook behaal met otoliete van ander vissoorte, naamlik stokvis *Merluccius capensis,* koningklip *Genypterus capensis,* witsteenbras *Lithognathus lithognathus,* kabeljou *Johnius hololepidotus,* panga *Pterogymnus laniarius,* Weskustongvis *Austroglossus microlepis,* snoek *Thyrsites atun,* makriel *Scomber japonicus,* dikkop *Sufflogobius bibarbatus,* sardyn *Sardinops ocellata* en ansjovis *Engraulis capensis.*

Otoliete wat nie in 'n oop vlam gebrand kan word nie, of wat baie maklik breek of beskadig word met die hantering daarvan, kan met toepassing van hierdie tegniek gebrand word. Otoliete van sardyn en ansjovis verbrokkel of "ontplof" eenvoudig na twee sekondes in 'n oop vlam, terwyl geen verbrokkeling plaasvind as dit op 'n lemmetjie gebrand word nie (Fig. 2). Alhoewel die brand van sardyn-otoliete nie die leesbaarheid van hierdie otoliete verbeter nie, bewys dit egter dat otoliete met soortgelyke neigings tot verbrokkeling oor 'n oop vlam, wel op 'n metaalplaatjie gebrand kan word.

Die otoliete van snoek is baie dun en breek maklik met die hantering daarvan. Die brand van laasgenoemde otoliete op 'n metaalplaatjie, skakel onnodige hantering met 'n tangetjie uit.

Egalige verbranding van groot otoliete, soos dié van witsteenbras, koningklip en panga wat in meerdere of mindere mate geboë is, kan verkry word deur die metaalplaatjie effens in te duik sodat die groots moontlike oppervlak van die otoliet se konvekse vlak aan die metaal raak.

Vir dik otoliete met 'n knobbelrige sentrale gedeelte, soos dié van die kabeljou, word aanbeveel dat die otoliet eers in 'n transversale vlak deur die knopvormige sentrale gedeelte deurgesaag word. Die helftes van die otoliet word dan met die snyvlak op die metaalplaatjie geplaas en gebrand.

Die aanwending van hierdie tegniek vir die brand van otoliete hou dus besliste voordele in vir die ouderdomsbepaling van vis en bied 'n oplossing vir probleme soos onegalige verbranding, maklike oorverbranding, kraak van otoliete, onnodige hantering van die otoliete tydens die brandproses en dié wat ontstaan met die brand van otoliete wat in 'n oop vlam verbrokkel of "ontplof".

LITERATUUR AANGEHAAL

BLACKER, R. W. 1969 — Chemical composition of the zones in cod (*Gadus morhua* L) otoliths. *J. Cons. perm. int. Explor. Mer* **33** (1): 107-108.

CHRISTENSEN, J. M. 1964 — Burning of otoliths, a technique for age determination of soles and other fish. *J. Cons. perm. int. Explor. Mer* **29** (1): 73-81.

GELDENHUYS, N. D. 1973 — Growth of the South African maasbanker *Trachurus trachurus* Linnaeus and age composition of the catches, 1950-1971. *Investl Rep. Sea Fish. Brch S. Afr.* **101**:24 pp.

MACER, C. T. 1977 — Some aspects of the biology of the horse mackerel [*Trachurus trachurus* (L.)] in waters around Britain. *J. Fish Biol.* **10**(1):51-62.

MAY, A. W. 1965 — The validity of otolith ages of Southern Grand Bank cod. *Res. Bull. int. Commn Northw. Atlant. Fish.* **2**:19-24.

Fish. Bull. S. Afr. 12:53–68
1979

OOCYTE DEVELOPMENT AND SPAWNING FREQUENCY IN THE SOUTH WEST AFRICAN PILCHARD *SARDINOPS OCELLATA*

F. LE CLUS

Spawning frequency in the South West African pilchard *Sardinops ocellata* was investigated. The study was based on the diameter distribution of yolked oocytes in relation to the stage of development. Two size classes of yolked oocytes were found, suggesting that two batches could be spawned within a season. The presence of unimodal ovaries during the second half of the spawning season suggested that some ovaries were maturing after the most advanced size class had been shed.

Kuitskietfrekwensie in die Suidwes-Afrikaanse sardyn *Sardinops ocellata* is ondersoek. Die studie is baseer op die deursnitdistribusie van eiergeelbevattende oösiete met betrekking tot die stadium van ontwikkeling. Twee grootteklasse van dooierbevattende oösiete is gevind, wat suggereer dat die sardyn twee keer binne 'n seisoen kan kuitskiet. Die teenwoordigheid van ovaria met 'n enkele modus van eiergeelbevattende oösiete gedurende die tweede helfte van die kuitskietseisoen dui daarop dat sommige ovaria besig was om te ontwikkel nadat die mees gevorderde grootteklas uitgestort is.

This work forms part of an investigation into the reproductive potential of the pilchard *Sardinops ocellata* (Pappe) off South West Africa. The number of times an individual fish can spawn within one spawning season is an important factor in assessing the reproductive potential of a species.

Matthews (1964) established that the spawning season of the South West African pilchard was protracted and usually extended from June or July in one year to April the following year, with two spawning peaks, one over August/September and another over February/March. An extended spawning season with two peaks could result either from individual fish from two separate stocks spawning only once during a specific spawning season, or from individual fish from one stock spawning twice during the same season. The existence of either one or two stocks has not yet been proved for the South West African pilchard. King (1977) found, from the distribution of planktonic eggs, that the two spawning peaks occurred in distinct areas and within different temperature ranges. This, he suggested, indicated the possible existence of two spawning stocks. On the other hand, Matthews (*op. cit.*) found two peaks in the mean monthly gonad mass of pilchard caught near Walvis Bay. The two peaks of gonad mass corresponded in timing with the peaks of spawning and could have been an indication that the same stock was spawning twice.

Hickling and Rutenberg (1936) and MacGregor (1976) suggested that some inferences may be drawn from the size distribution of oocytes in the ovaries. In this study, the frequency distribution of yolked oocytes in the ovaries of the pilchard is presented.

In related species, such as the Californian sardine *Sardinops caerulea* (Clark 1934, MacGregor 1957) and the European pilchard *Sardina pilchardus* (Andreu and Dos Santos Pinto 1957), at least two modes of yolked oocytes were found in later stages of development. This was also the case with *Sardinops ocellata* but, in addition, unimodal ovaries were found in advanced maturity stages (late active). Unimodal ovaries may occur if, after the first spawning, the next mode of yolked oocytes continues to develop. The frequency distribution of these unimodal ovaries was analysed in relation to maturity stage and month in order to clarify the frequency of spawning.

A description of changes in oocyte size and related changes in the ovaries of the pilchard throughout their seasonal reproductive cycle would assist in determining the relationship between the cycle and the assignment of maturity stages. Such a description would also provide basic information for studying such subjects as fecundity and rates of development.

Only yolked oocytes have been considered in this study because the presence of yolk has often been accepted as a criterion for the identification of oocytes potentially capable of release in the same spawning season (Macer 1974).

MATERIAL AND METHODS

Female pilchard were obtained off South West Africa from the area between Cape Frio and Lüderitz. The majority were collected between Walvis Bay and Palgrave Point (Fig. 1) during the period June 1972-October 1974 (Table I). The geographical distribution of the fish sampled coin-

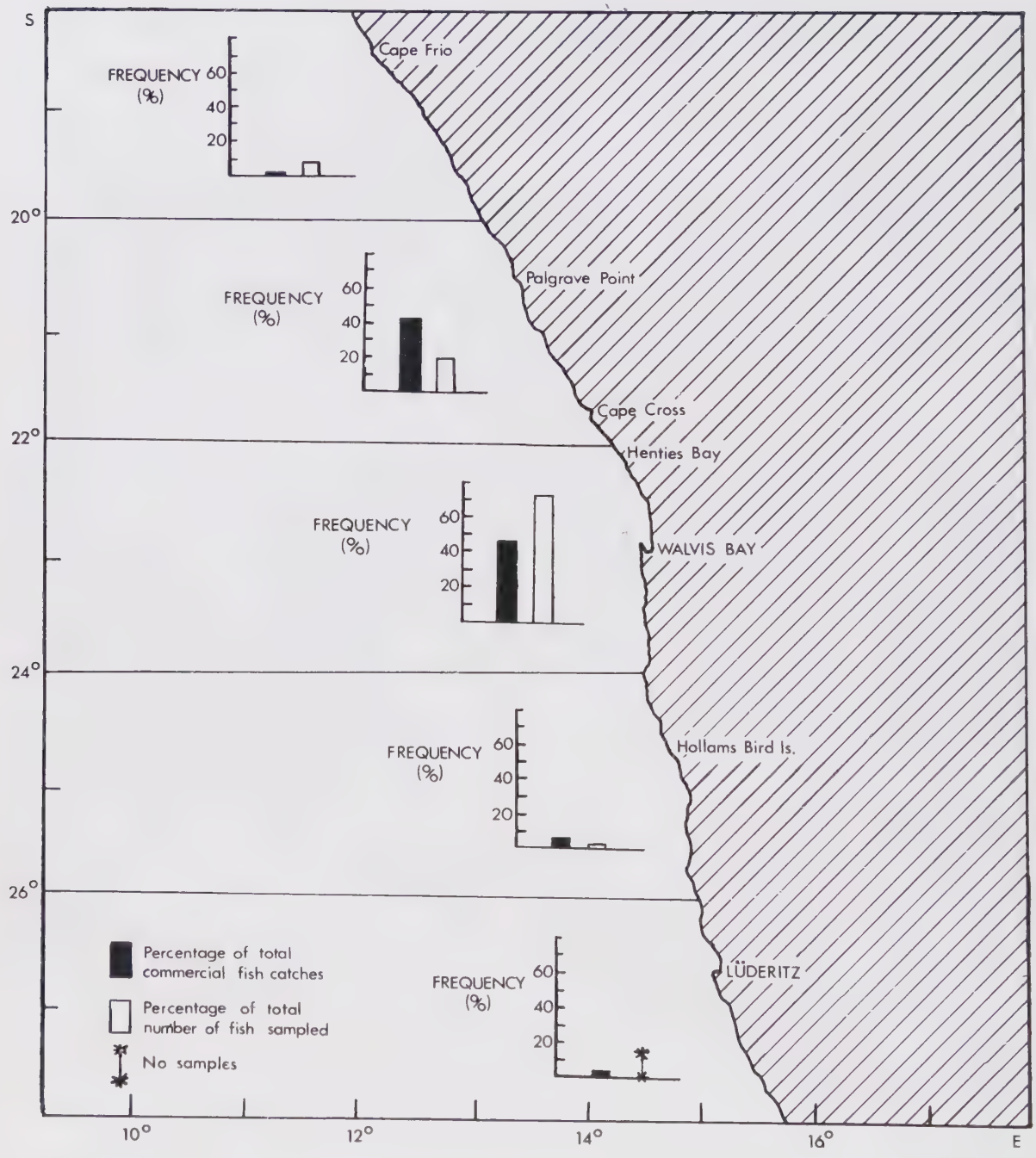

Fig. 1: Distribution of pilchard catches and samples for each 2 degrees of latitude — cumulative from June 1972 to October 1974

Table I: Female pilchard analysed between June 1972 and October 1974

Spawning period	Month	Catch latitude (South)*	Number of fish
Winter-Spring 1972	June†	22°00′ – 23°40′	27
	July†	22°50′ – 24°30′	13
	August†	21°40′ – 24°30′	24
	September†	21°40′ – 23°20′	28
Summer-Autumn 1972/73	November†	21°40′	25
	December†	19°10′ – 23°20′	27
	January†	21°00′ – 23°00′	153
	February	21°10′	3
	March†	23°00′	28
Winter-Spring 1973	August†	21°20′ – 23°00′	18
	October†	21°00′	8
Summer-Autumn 1973/74	November†	22°40′	31
	December†	22°40′	29
	January†	23°00′	31
	February†	19°50′ – 23°00′	54
	March†	23°00′	24
Winter-Spring 1974	June	23°00′	22
	July	23°00′	46
	August	20°30′ – 23°10′	10
	September	18°00′ – 22°30′	77
	October	22°10′	31
Total			709

* Approximate positions obtained from commercial fishing vessels
† Fish used to illustrate oocyte development

cided in general with the distribution of commercial fish catches.

Ovaries were prepared as described by Le Clus (1977), Gilson's fluid being used to separate the oocytes. In a random subsample, the diameter distributions of the yolked oocytes for each fish were grouped into size classes of 62,5 μ. Measurement of the oocyte diameter was fairly uncomplicated because in the ovary the oocyte size and the yolk size are the same.

In those ovaries in which the bimodal distribution of yolked oocytes overlapped to a large extent, the cut-off point between the modes was established by using normal probability paper and polymodal frequency analysis as described by Harding (1949). The average volume of each mode was then calculated separately using the formula for a sphere

$$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3$$

where d = oocyte diameter in millimetres.

THEORY AND RESULTS

Because this study of ovarian development is concerned with yolked oocytes, only maturity stages from early active to ripe-running were analysed. Most definitions and terminology used are in accordance with Davies (1956) and Matthews (1964). Table II gives the relationships between the macroscopic descriptions of maturity stage according to Davies (*op. cit.*) and the microscopically determined mean volumes of the most advanced mode of yolked oocytes.

Most female pilchard with maturing oocytes examined prior to spawning had, in addition to a large number of small yolkless oocytes ("reserve-fund" oocytes) a bimodal distribution of yolked oocytes (Fig. 2). However, some females with ripe-running ovaries had a third mode of small yolked oocytes. The most advanced yolked oocytes were called the last (spawning) mode and the less advanced, the intermediate mode, owing to the occasional presence of the small mode (Fig. 2).

Some issues of ovarian development in the pilchard should be clarified before proceeding.

Pilchard are found in all stages of development during the spawning season. Ovarian development was, therefore, not summarized on a monthly basis but according to the mean oocyte size of the last-mode oocytes. For the same reason, although absolute mean ovary mass has often been used to indicate the seasonal spawning cycle of fish, it is not a good criterion on which to base the stage of maturity of pilchard. A further disadvantage of using absolute ovary mass is that, even though it increases in individual fish as the oocytes develop, the increase depends on oocyte number as well as oocyte size, while the number in turn proliferates with fish size.

Table II: Stages of ovary development related to volume of last-mode oocytes

Maturity stage	Symbol	Classes of last-mode oocyte mean volume (mm^3)
Early active	3a	$0{,}01 \leq V < 0{,}05$
Active	3b	$0{,}05 \leq V < 0{,}10$
Late active	3c	$0{,}10 \leq V < 0{,}15$
Active-ripe	4	$0{,}15 \leq V < 0{,}20$
Ripe	5	$0{,}20 \leq V < 0{,}35$
Ripe-running	6	$0{,}35 \leq V$

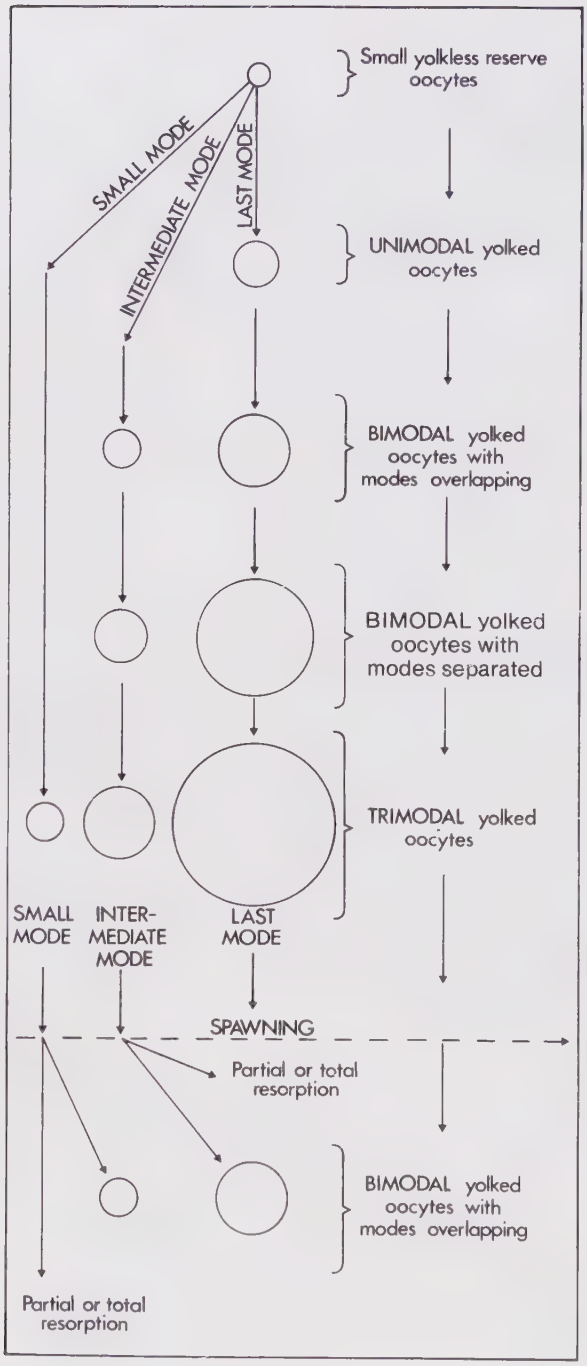

Fig. 2: Flow diagram of the sequence of yolked-oocyte formation during development

Oocytes continue to increase in size while in the ovary. Thus, oocyte size can be used as one of the criteria on which the stage of development of the ovary can be based. After spawning, there is a sudden increase in the size of the fertilized egg (planktonic egg) owing to the formation of a large perivitelline space generally characteristic of *Sardinops* species. The perivitelline space is formed by fluid accumulating between the egg membrane (zona radiata) and the vitelline membrane. Thus, before spawning, oocyte size and yolk size are the same, whereas after spawning the difference is considerable.

Formation and fate of oocytes

In the process of growth, the oocyte passes through two phases. The first is one of slow growth, which results in the formation of small, yolkless primary oocytes, whereas the second, rapid phase involves the deposition of large amounts of yolk (Ball 1960). Oocytes containing yolk (the maturing oocytes) have a layer of granulosa cells, whereas those without yolk (the resting oocytes) have no granulosa layer. Further development of the maturing oocytes is dependent on this granulosa layer which has a nutritive function during vitellogenesis (Ball *op. cit.*, Bowers and Holliday 1961). Increase in the size of the ovary of specific fish during a reproductive cycle therefore depends on the growth of the individual oocytes and not on an increase in the number of maturing oocytes.

The growth, maturation and ovulation of oocytes will be described on the basis of Figure 3. The fish were divided into developmental stages according to the mean volume of the last-mode oocytes, which was stratified into 0,01-mm^3 size classes, and the diameter distribution for each class was plotted in Figure 3. From these graphs, the diameter changes of last-mode oocytes and their associated intermediate mode (also plotted on Figure 3) could be related to macroscopic stages of ovarian development (Fig. 2) and concomitant changes in the oocyte.

Formation of new oocytes — Before the development of yolked oocytes is discussed, a summary of the history of early developing oocytes is necessary. In many species of fish, a reserve fund of small yolkless oocytes is present in the ovaries at all maturity stages except in immature fish. It is absent, however, in species that spawn only once in their lifetime (Yamomoto and Yamazaki 1961). In pilchard from South West Africa, these reserve-fund oocytes vary in diameter between 50 μ and 185 μ.

Three of the current theories on the replenishment of the reserve fund are:

(i) Oogonia divide annually by mitosis to increase the number of potential oocytes (still diploid).

(ii) Follicle cells transform into oocytes within the ovigerous lamellae.

(iii) The full complement of oocytes is present at first maturity.

In the report of Foucher and Beamish (1977) these theories are discussed and summarized but no conclusion is reached.

Early development — In ovaries recorded as "inactive" or "inactive-active", essential reproductive processes nevertheless occur. According to various workers (Balinsky 1975, Hilge 1975), oogonia eventually change into primary oocytes, which are characterized by the presence of nucleoli and a single-layered follicle. Slow protoplasmic growth takes place in the young oocyte and then the premeiotic prophase commences. This continues only until the intimately paired homologous chromosomes begin to repel each other (diplotene), i.e. before the first maturation division has taken place, and thus the oocyte is still diploid. During the subsequent phase of vitellogenesis, all chromosomal activity is suspended but important changes in the configuration of the oocytes take place. The nucleoli pass into the cytoplasm, vacuoles appear at the periphery of the oocytes and the follicle becomes double-layered. The oocyte volume increases as yolk formation continues.

Active ovaries (Fig. 3.1-3.14) — In active ovaries, the oocytes were found to be visible to the naked eye. In early active ovaries (Fig. 3.1-3.4), there is at first only one mode of yolked oocytes. As development proceeds, a second mode (the intermediate mode) of yolked oocytes is formed from non-yolked primary oocytes entering vitellogenesis. In the more advanced mode, or last mode, yolk deposition only proceeds until these oocytes reach a volume of about 0,09 mm^3 (Fig. 3.9) — Le Clus (in press). These oocytes now enter the maturation phase. Further increases in oocyte volume are mainly due to fluid uptake.

As the ovary enters the active stage (Fig. 3.5), the second mode of yolked oocytes becomes discernible. The separation between the two modes increases and is complete in the majority of ovaries at the beginning of the active-ripe stage (Fig. 3.15). The mean volumes of the intermediate-mode oocytes now range between 0,01 and 0,03 mm^3, which is equivalent to the mean volume of last-mode oocytes found in early active ovaries. There is usually no further increase in the mean volume of intermediate-mode oocytes until ovulation.

Active-ripe to ripe ovaries (Fig. 3.15-3.34) — The active-ripe and ripe maturity stages are both still part of the maturation phase. In the maturation phase, meiotic divisions resume and the phase ends when the last-mode oocytes become ova (ripe eggs) after the second maturation division (Hilge 1975). According to Arndt (1960, quoted from Hilge *op. cit.*), the first maturation division in fish takes place shortly before ovulation. The second maturation division can take place at the time of spawning and penetration of the sperm (Harder 1964, quoted from Hilge *op. cit.*). Thus, during the major part of development, the oocyte is diploid.

During oocyte maturation, the yolk becomes transparent as the yolk globules fuse and the nucleus moves from the centre of the oocyte to the periphery (Smith 1957). The oocyte volume increases rapidly as fluid with a specific gravity lower than seawater is secreted by the granular cells of the follicle (Fulton 1895, Milroy 1898, both quoted by Smith *op. cit.*).

In *Sardinops ocellata*, water uptake continues until all the last-mode oocytes are transparent and, because they are still in the follicle, the fresh, ripe ovary looks like a translucent jelly with a yellow-pink tint, stippled by the small, opaque-yellow intermediate oocytes. Oocyte volume is approximately 0,15-0,35 mm^3 (Fig. 3.15-3.34). The oil globule is visible in the last-mode oocytes as they become transparent.

Ovulation (Fig. 3.35-3.44) — Follicle maturation is necessary before ovulation can take place and runs concurrently with oocyte maturation (Jalabert 1976). Before ovulation, the space between follicle cells and oocytes is bridged by cytoplasmic processes (microvilli) which increase the surface area between them (Balinsky 1975). In preparation for ovulation, the cytoplasmic processes are withdrawn leaving perforations in the oocyte membrane.

During ovulation the ripe oocyte is released from its follicle. It appears that, in teleosts, all ripe oocytes are released simultaneously from the follicles into the ovarian lumen (Bowers and Holliday 1961; Kraft and Peters 1963, quoted by Baird 1974). In *Sardinops ocellata*, advanced stages of maturity have been noted with either all of the last-mode oocytes ovulated or with all still in the follicles. No partial ovulation has been observed, i.e. no ovaries have been found with both ovulated and non-ovulated ripe oocytes. This would seem to indicate

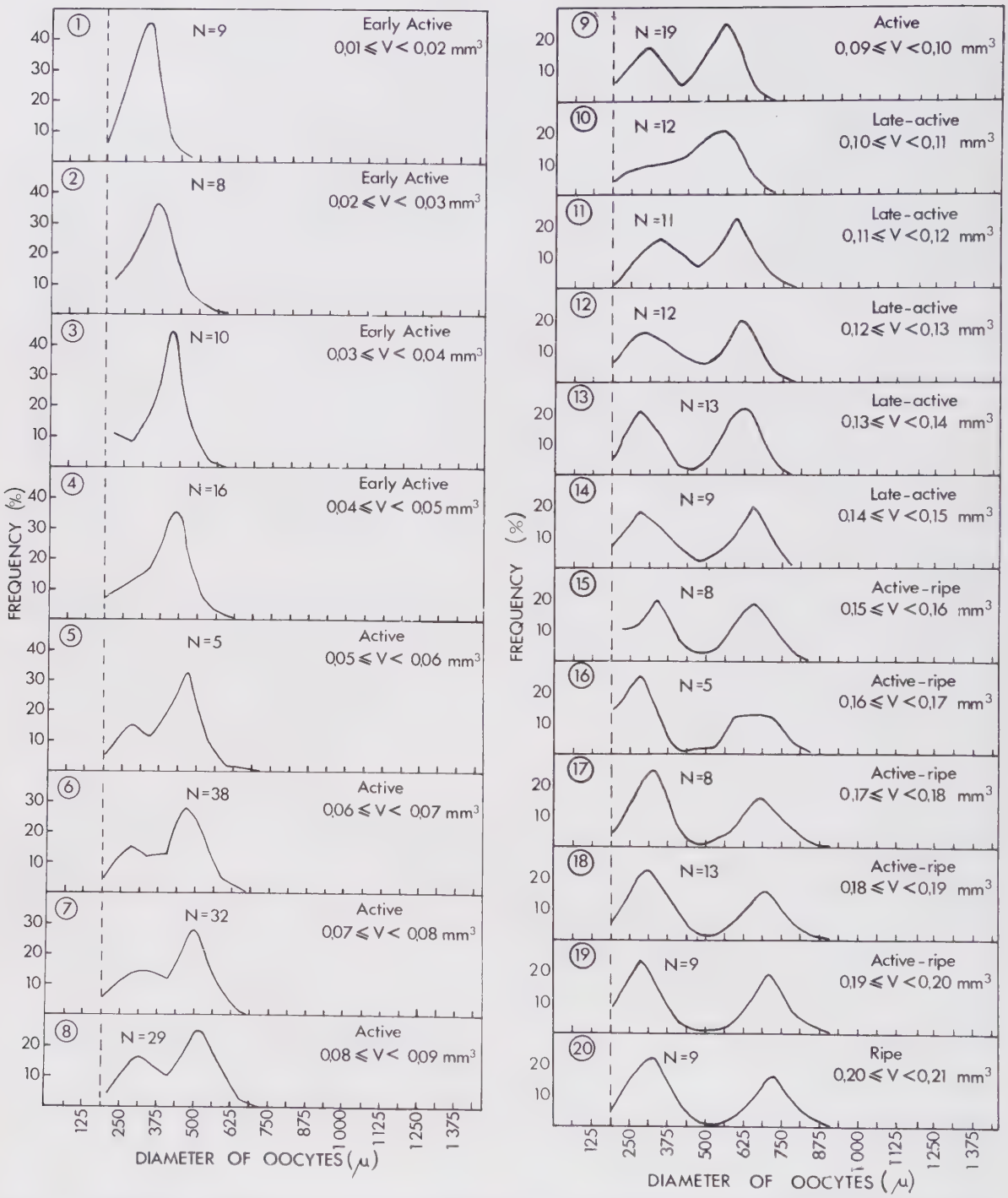
FREQUENCY (%)
DIAMETER OF OOCYTES (μ)
1 Early Active 0,01 ≤ V < 0,02 mm³ N=9
2 Early Active 0,02 ≤ V < 0,03 mm³ N=8
3 Early Active 0,03 ≤ V < 0,04 mm³ N=10
4 Early Active 0,04 ≤ V < 0,05 mm³ N=16
5 Active 0,05 ≤ V < 0,06 mm³ N=5
6 Active 0,06 ≤ V < 0,07 mm³ N=38
7 Active 0,07 ≤ V < 0,08 mm³ N=32
8 Active 0,08 ≤ V < 0,09 mm³ N=29
9 Active 0,09 ≤ V < 0,10 mm³ N=19
10 Late-active 0,10 ≤ V < 0,11 mm³ N=12
11 Late-active 0,11 ≤ V < 0,12 mm³ N=11
12 Late-active 0,12 ≤ V < 0,13 mm³ N=12
13 Late-active 0,13 ≤ V < 0,14 mm³ N=13
14 Late-active 0,14 ≤ V < 0,15 mm³ N=9
15 Active-ripe 0,15 ≤ V < 0,16 mm³ N=8
16 Active-ripe 0,16 ≤ V < 0,17 mm³ N=5
17 Active-ripe 0,17 ≤ V < 0,18 mm³ N=8
18 Active-ripe 0,18 ≤ V < 0,19 mm³ N=13
19 Active-ripe 0,19 ≤ V < 0,20 mm³ N=9
20 Ripe 0,20 ≤ V < 0,21 mm³ N=9
125 250 375 500 625 750 875 1000 1125 1250 1375

Fig. 3: Size frequency distribution of yolked oocytes per 0,01-mm³ volume class (oocytes less than 187,5 μ diameter removed with Endocott sieves)

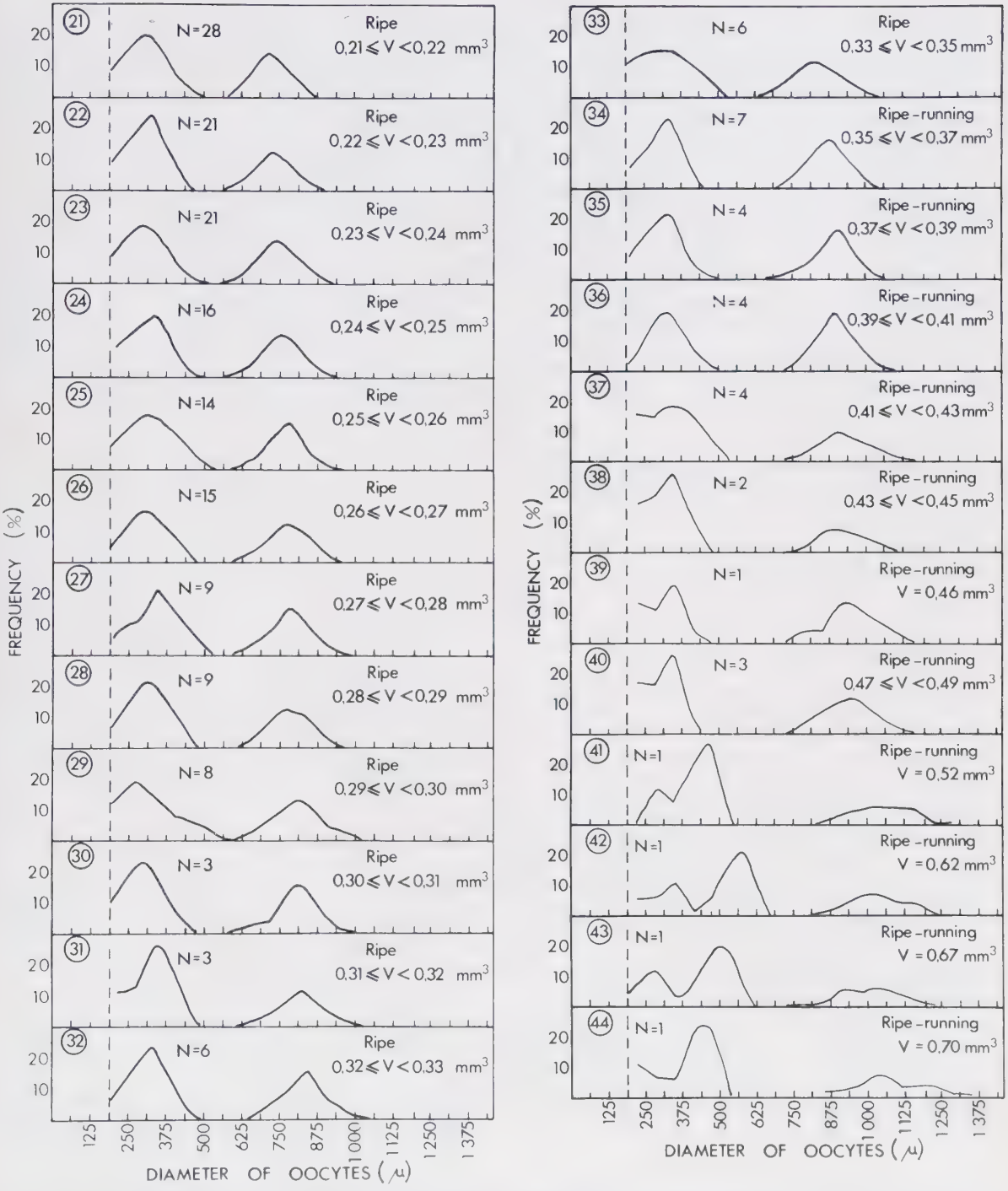
21 N=28 Ripe 0,21 ≤ V < 0,22 mm³
22 N=21 Ripe 0,22 ≤ V < 0,23 mm³
23 N=21 Ripe 0,23 ≤ V < 0,24 mm³
24 N=16 Ripe 0,24 ≤ V < 0,25 mm³
25 N=14 Ripe 0,25 ≤ V < 0,26 mm³
26 N=15 Ripe 0,26 ≤ V < 0,27 mm³
27 N=9 Ripe 0,27 ≤ V < 0,28 mm³
28 N=9 Ripe 0,28 ≤ V < 0,29 mm³
29 N=8 Ripe 0,29 ≤ V < 0,30 mm³
30 N=3 Ripe 0,30 ≤ V < 0,31 mm³
31 N=3 Ripe 0,31 ≤ V < 0,32 mm³
32 N=6 Ripe 0,32 ≤ V < 0,33 mm³
33 N=6 Ripe 0,33 ≤ V < 0,35 mm³
34 N=7 Ripe-running 0,35 ≤ V < 0,37 mm³
35 N=4 Ripe-running 0,37 ≤ V < 0,39 mm³
36 N=4 Ripe-running 0,39 ≤ V < 0,41 mm³
37 N=4 Ripe-running 0,41 ≤ V < 0,43 mm³
38 N=2 Ripe-running 0,43 ≤ V < 0,45 mm³
39 N=1 Ripe-running V = 0,46 mm³
40 N=3 Ripe-running 0,47 ≤ V < 0,49 mm³
41 N=1 Ripe-running V = 0,52 mm³
42 N=1 Ripe-running V = 0,62 mm³
43 N=1 Ripe-running V = 0,67 mm³
44 N=1 Ripe-running V = 0,70 mm³
FREQUENCY (%)
20
10
125 250 375 500 625 750 875 1000 1125 1250 1375
DIAMETER OF OOCYTES (μ)

Fig. 3 (*cont.*): Size frequency distribution of yolked oocytes per 0,01-mm³ volume class (oocytes less than 187,5 μ diameter removed with Endocott sieves)

that ovulation in the pilchard takes place over a comparatively short period. A similar rapid ovulation was found in the European pilchard *Sardina pilchardus* by Andreu and Dos Santos Pinto (1957).

In the South West African pilchard, ovulation has been noted when the last-mode oocytes have reached 0,38 mm^3 in volume (Table III), but size at ovulation is variable because one fish caught in March 1974 had non-ovulated, last-mode oocytes with a volume of 0,52 mm^3. After ovulation, the ovulated oocytes lie free in the lateral lumen ("oviduct") and absorb the ovary fluid. In the South African pilchard, spawning takes place when the diameter of last-mode oocytes is approximately 1,2 mm (Davies 1956). The size of oocytes at spawning has not been determined for the South West African pilchard, even though it is the same species.

Table III: Mean oocyte volumes of intermediate-mode and last-mode oocytes of ripe-running female pilchard, October 1973

Mean oocyte volume (mm^3)		Last mode ovulated or not	Standard length (mm)
Last mode	Intermediate mode		
0,38	0,01	Yes	223
0,42	0,02	No	194
0,42	0,04	No	212
0,57	0,03	Yes	214
0,60	0,03	Yes	217
0,62	0,09	Yes	214
0,69	0,06	Yes	212
0,70	0,06	Yes	212

The dorso-lateral portion of the ovary wall, where the lumen forms, is completely without lamellae (septa) as is that of *Sardina pilchardus* (Andreu and Dos Santos Pinto 1957). In this the pilchard differs from fish such as the mackerel *Scomber japonicus* where the lumen is surrounded by septa (Baird 1974). In active ovaries, the space between the dorso-lateral portion of the ovary wall and the septa is small. After ovulation, this space is much enlarged to contain the ovulated oocytes, while much-reduced septa retain immature and developing oocytes. After spawning, the free ovary wall contracts and again lies close to the septa. Thus, immediately after spawning the ovary may have the appearance of an active ovary.

Post-spawning stages — In *Sardinops ocellata,* as well as in other fish (Andreu and Dos Santos Pinto 1957, Simmons 1969), it is difficult to recognize the post-spawning stages because identical oocyte sizes may be found in post-spawning, inactive-active and active ovaries. The only difference is the presence of the remnants of mature oocytes in the post-spawning stage. By macroscopic examination, these remnants of ripe-running oocytes in a fresh, post-spawned ovary are not seen and hence the ovary is classified as "active". This is so because the ripe oocytes are delicate and transparent, as is the case in the Californian pilchard (Clark 1934).

A post-spawning ovary can have the gonad mass expected of active ovaries. The residual mass of a ripe-running gonad was found to be 4,2 g after the ovulated oocytes had been removed. The outward appearance of this ovary was then consistent with that of an active ovary because the distended lateral "oviduct" shrank as the ovulated oocytes flowed out. The intermediate-mode oocytes remained and were opaque and clearly visible to the naked eye.

Spent ovaries — Fresh ovaries macroscopically classified as spent were examined through a dissection microscope. Many minute blood vessels surrounding young oocytes were found, resulting in the wine-red appearance of the spent ovary. These blood vessels could accelerate resorption of yolk and rearrangement of the follicle cells into reserve-fund oocytes. Through partial resorption, abortive oocytes could be rejuvenated into young and healthy but smaller oocytes, as Yamamoto (1956) found in the flounder *Liopsetta obscura.* These rejuvenated oocytes could be the next season's crop. Rearrangement of empty follicles is quick, e.g. in the medaka *Oryzias latipes* they disappeared within three days (Yamamoto and Yoshioka 1964).

Ovaries with one mode of yolked oocytes

With the exception of the early-active stage, the descriptions so far have referred to ovaries with more than one mode of yolked oocytes. However, occasionally only one mode of yolked oocytes is found in the active to late-active ovaries.

These ovaries could have been unimodal because the intermediate-mode oocytes had continued to develop after the shedding of the most advanced mode, whereas a new group of yolked oocytes had not yet developed from the reserve of yolkless oocytes. Hence, the seasonal occurrence of these unimodal ovaries may be important in determining spawning frequency.

The ovaries of each fish were recorded as either bimodal or unimodal. Table IV reflects the relationships between the frequency of unimodal ovaries

Table IV Seasonal collection of fish with a unimodal distribution of yolked oocytes

Classes of last-mode oocyte mean volume (mm^3)	Winter-Spring						Summer-Autumn					
	Number of fish					Percentage of unimodal ovaries	Number of fish					Percentage of unimodal ovaries
	1972 + 1973 Jun. — Oct.		1974 Jun. — Oct.		Total		1972/73 Nov. — Mar.		1973/74 Nov. — Mar.		Total	
	Unimodal	Total	Unimodal	Total			Unimodal	Total	Unimodal	Total		
$0,01 \leq V < 0,02$*	—	—	—	—	—	—	9	9	—	—	9	100
$0,02 \leq V < 0,03$*	—	—	—	—	—	—	8	8	—	—	8	100
$0,03 \leq V < 0,04$	0	1	0	0	1	0,0	5	5	3	4	9	88,9
$0,04 \leq V < 0,05$	0	2	0	5	7	0,0	4	4	9	11	15	86,7
$0,05 \leq V < 0,06$	1	6	0	9	15	6,7	3	10	18	35	45	46,7
$0,06 \leq V < 0,07$	1	6	0	15	21	4,8	3	12	6	20	32	28,1
$0,07 \leq V < 0,08$	2	7	0	26	33	6,1	2	7	9	18	25	44,0
$0,08 \leq V < 0,09$	0	7	0	25	32	0,0	1	5	4	17	22	22,7
$0,09 \leq V < 0,10$	0	5	0	15	20	0,0	2	8	1	6	14	21,4
$0,10 \leq V < 0,11$	0	4	0	11	15	0,0	2	4	2	4	8	50,0
$0,11 \leq V < 0,12$	0	4	0	10	14	0,0	0	5	1	2	7	14,3
$0,12 \leq V < 0,13$	0	5	0	8	13	0,0	1	2	0	5	7	14,3
$0,13 \leq V < 0,14$	0	4	0	11	15	0,0	1	4	1	5	9	22,2
$0,14 \leq V < 0,15$	0	4	0	4	8	0,0	0	5	0	0	5	0,0
Total	4	55	0	139	194		24	71	54	127	198	
Percentage unimodal	7,3		0,0			2,1	33,8		42,5			39,4

* Not included in totals

and the stage of development and the season. The frequency of unimodal ovaries decreased with developmental stage. Ovaries with mean oocyte volumes between 0,01 and 0,03 mm^3 were unimodal, but all ovaries were bimodal by the time the last-mode oocytes had a volume of 0,15 mm^3 (Table IV).

Unimodal ovaries were not found in equal numbers throughout the year. During winter-spring 1972 and 1973, only four were found (Table IV). These ovaries were classified macroscopically and microscopically as active (mean oocyte volume 0,05-0,09 mm^3). During winter-spring 1974, no unimodal ovaries were collected (Table IV). However, 33,8 and 42,5 per cent of active and late-active ovaries collected during summer-autumn 1972/73 and 1973/74 respectively, were unimodal (Table IV).

A monthly analysis showed that, during summer-autumn 1972/73, unimodal ovaries occurred from November to January, mostly in the latter month (Table V). The three active ovaries collected in February were bimodal. During summer-autumn 1973/74, unimodal ovaries were collected from December to February with again the highest percentage in January. All 13 active to late-active ovaries collected in March 1974 were bimodal (Table V).

The frequency of unimodal ovaries could not be related directly to peaks of spawning as deduced from planktonic egg abundance. However, unimodal ovaries may be a feature of summer spawning when temperatures are higher, thus favouring faster oocyte development. Heavy summer spawning in 1972/73, as depicted by planktonic egg concentrations, was found in November and again in January, but the heaviest spawning was found at the end of the spawning season in February and March (King 1974). During the summer of 1973/74, spawning peaked in January and again in March, the latter being the heaviest of the year (Sea Fisheries Branch, unpublished data). It is possible that unimodal ovaries occur more often when the autumn spawning is heavier than the spring spawning.

Separation of oocyte modes

The issue of separation between oocyte modes is important because, once separation between the

Table V: Monthly frequency of fish with one mode of yolked oocytes (0,03 — 0,15 mm³) collected during summer-autumn

Month	1972/73			1973/74		
	Unimodal	Total	Percentage unimodal	Unimodal	Total	Percentage unimodal
November	7	22	31,8	—	—	—
December	1	19	5,3	7	29	24,1
January	16	27	59,3	20	28	71,4
February	0	3	0,0	27	54	50,0
March	—	—	—	0	13	0,0

modes is complete, the batch size of the last-mode oocytes is determined. The separation marks the faster development of the last mode compared to that of the intermediate mode. Should, after separation, any intermediate-mode oocytes develop into last-mode oocytes or the opposite occur as a result of partial resorption, movement of oocytes between modes would have been detected.

Bimodal fish were classified as having overlapping modes of oocytes or having the modes separated. Two modes of oocytes were considered to be separated when one diameter unit interval (62,5 μ) between the two class sizes contained less than 5 per cent of the total number of yolked oocytes measured for a particular fish. The frequencies of these fish with two modes separated were recorded as a percentage of all the fish (unimodal and bimodal) collected in a particular developmental stage and are given separately for winter-spring and summer-autumn (Table VI).

In winter-spring, separation of modes occurred in a higher percentage of fish with early-active to late-active ovaries ($0 < V < 0,15\ mm^3$) than in summer-autumn (Fig. 4). The implication may be that batch size is determined somewhat earlier in development during winter-spring than in summer-autumn. Batch size could therefore be slightly more adaptable in summer-autumn.

In many asynchronous fish species, complete separation of oocyte modes has rarely been observed, because the last stages of maturation may be completed in a few hours, as was found in the northern anchovy *Engraulis mordax* (Hunter and Goldberg, in press). However, complete separation has been observed in *Sardinops ocellata* (Table VII). It may be defined as the absence of any oocytes within one diameter unit interval of 62,5 μ between modes.

Total separation was initially more pronounced in winter-spring than in summer-autumn (Fig. 5). However, by the active-ripe (4) stage, the incidence of total separation during summer-autumn surpassed that of winter-spring. In summer-autumn, separation was complete by the end of the ripe (5c) stage, while during winter-spring separation was complete in only about 70 per cent of the ripe (5a) ovaries.

Table VI: Seasonal frequency of ovaries with separation between yolked oocyte modes at different stages of development

Classes of last-mode oocyte mean volume (mm³)	Winter-Spring			Summer-Autumn			Combined		
	Separation frequency		Sample* size	Separation frequency		Sample* size	Separation frequency		Sample* size
	Number	Percentage		Number	Percentage		Number	Percentage	
$0 < V < 0,05$	4	50	8	1	3	40	5	10	48
$0,05 \leq V < 0,10$	70	58	121	21	15	138	91	35	259
$0,10 \leq V < 0,15$	58	89	65	22	61	36	79	78	101
$0,15 \leq V < 0,20$	41	98	42	27	100	27	68	99	69
$0,20 \leq V < 0,25$	16	100	16	95	100	95	111	100	111
$0,25 \leq V < 0,30$	7	100	7	51	100	51	58	100	58
$0,30 \leq V < 0,35$	7	100	7	11	100	11	18	100	18
$0,35 \leq V < 0,40$	9	100	9	6	100	6	15	100	15

*Sample size includes both unimodal and bimodal ovaries

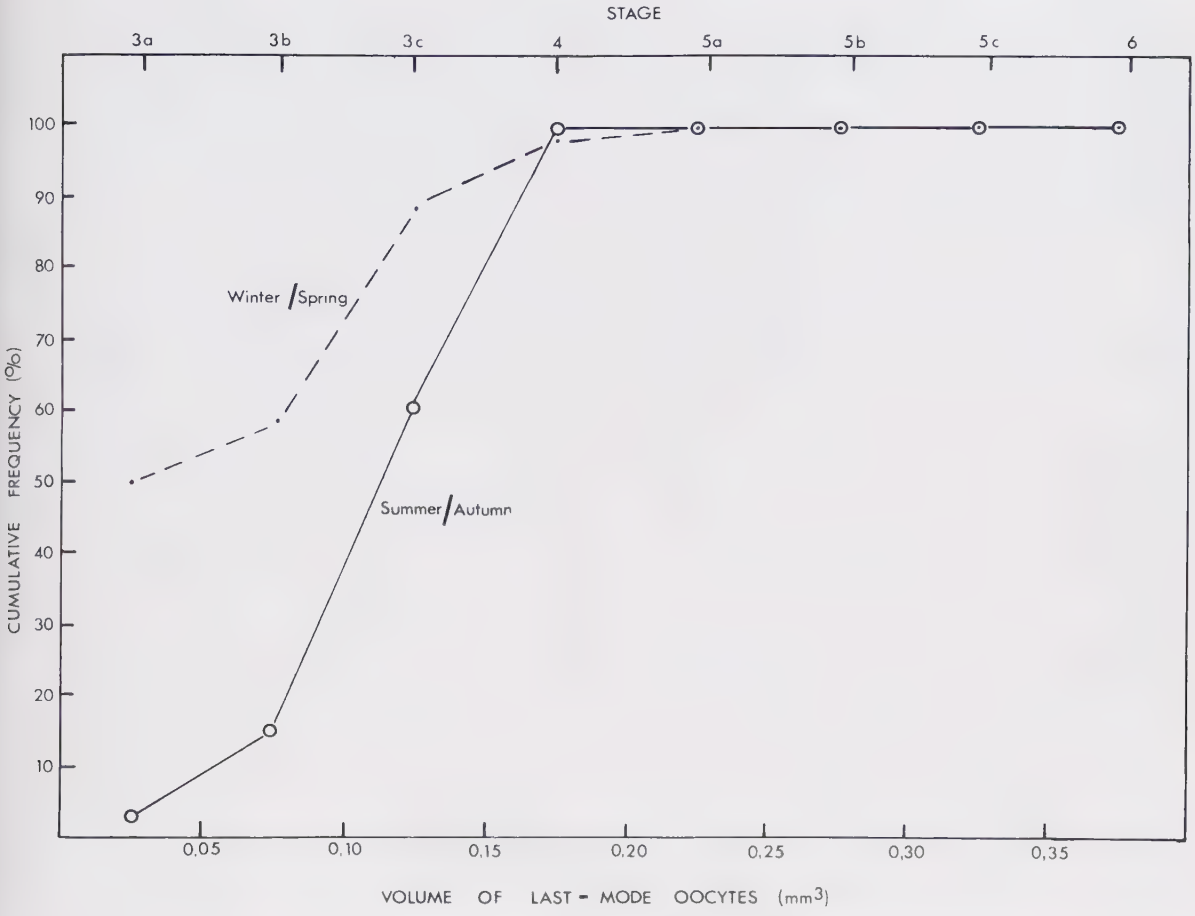

Fig. 4: Cumulative frequencies of winter-spring and summer-autumn ovaries where the intermediate and last modes have less than 5 per cent oocytes in common

Table VII: Seasonal frequency of ovaries with complete separation between yolked oocyte modes at different stages of development

Classes of last-mode oocyte mean volume (mm^3)	Winter-Spring			Summer-Autumn			Combined		
	Complete separation		Sample* size	Complete separation		Sample* size	Complete separation		Sample* size
	Number	Percentage		Number	Percentage		Number	Percentage	
$0 < V < 0{,}05$	0	0	8	0	0	40	0	0	48
$0{,}05 \leq V < 0{,}10$	14	12	121	1	1	138	15	6	259
$0{,}10 \leq V < 0{,}15$	25	38	65	7	19	36	32	32	101
$0{,}15 \leq V < 0{,}20$	26	62	42	20	74	27	46	67	69
$0{,}20 \leq V < 0{,}25$	11	69	16	72	76	95	83	75	111
$0{,}25 \leq V < 0{,}30$	5	71	7	47	92	51	52	90	58
$0{,}30 \leq V < 0{,}35$	5	71	7	11	100	11	16	89	18
$0{,}35 \leq V < 0{,}40$	9	100	9	6	100	6	15	100	15

*Sample size includes both unimodal and bimodal ovaries

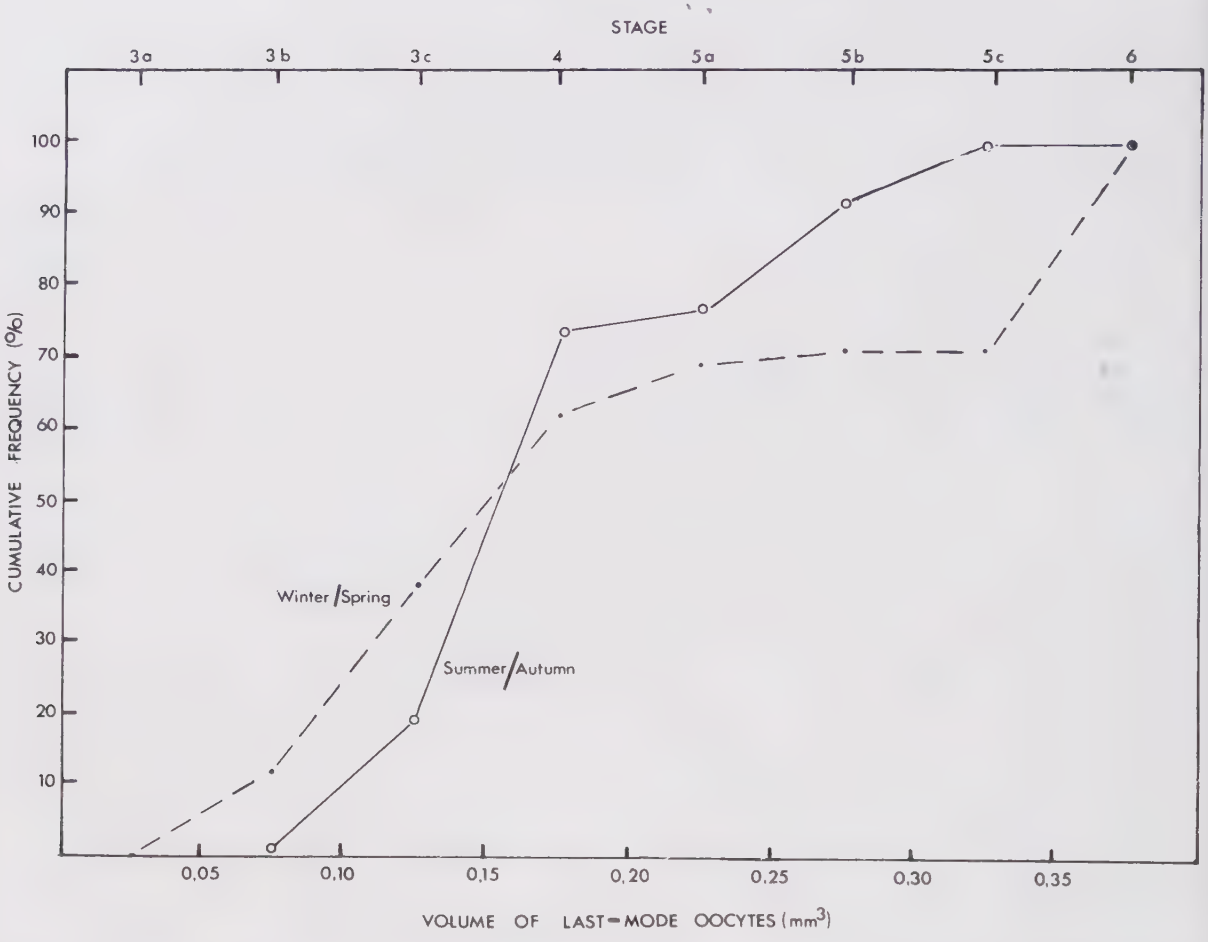

Fig. 5: Cumulative frequencies of ovaries where the intermediate mode is separated from the last mode by at least one size class (62,5 μ)

Also, it is apparent from Figure 5 that, from the active-ripe stage onwards, more than 50 per cent of the fish in each stage of development had complete separation between last and intermediate modes. This suggests that the later stages of oocyte maturation take place more slowly in *Sardinops ocellata* than in, for instance, *Engraulis mordax*.

In the South West African pilchard, the final batch size would, therefore, presumably be fixed by the time the oocytes enter the last phase of maturation.

ASYNCHRONISM AND SERIAL SPAWNING

A critical factor in the stock assessment of the South West African pilchard is the determination of the average number of eggs produced per year by each female. For this determination, it is necessary to ascertain the average number of oocytes spawned per batch and the number of spawnings.

There are three possible types of spawning:

(i) Total synchronism — only one group of yolked oocytes is found and only one spawning per life is known. To date, this has been identified in just two species, *Petromyzon planeri* and *Oncorhynchus masou* (Yamamoto and Yamazaki 1961). Once during the life of these fish, all oocytes develop synchronously to maturity, spawning takes place and the fish die.

(ii) Group synchronism — only one group of yolked oocytes is found and only one spawning occurs per season. It has been observed in a number of species, e.g. the herring *Clupea harengus* (Bowers and Holliday 1961), the flounder *Liopsetta obscura* (Yamamoto 1956), the eulachon *Thaleichthys pacificus* (Hart and McHugh 1944) and the Pacific herring *Clupea pallasi* (MacGregor 1957). Prior to the spawning season, the ovaries of these fish contain two groups of oocytes clearly distinguishable from each other. One group consists of large maturing oocytes which are to become the current season's crop. The other group is composed of small, yolkless oocytes which are retained in the ovary and are the recruitment stock for spawning in subsequent years. Fish displaying group synchronism usually spawn only once a year over a relatively short and well defined spawning season and may do so several times during their life.

(iii) Asynchronism — more than one group of yolked oocytes is found and multiple (serial) spawning recorded. Numerous fish display asynchronism and their ovaries contain oocytes in various stages of development prior to and during the spawning season. The presence of different size groups of yolked oocytes has been accepted as a criterion of the existence of multiple spawning by various authors, e.g. Clark (1925) for the grunion *Leuresthes tenuis*, Hart and McHugh (1944) for the silver smelt *Hypomesus pretiosus* and MacGregor (1957) for the Pacific sardine *Sardinops caerulea*. Fish displaying asynchronism have, in general, a spawning season which extends over several months during which they can spawn several times.

In species displaying asynchronism the number of spawnings is difficult to determine and, although the subject has been studied by a number of investigators, complete agreement has not yet been reached. The controversy centres around the question as to whether only the advanced group of yolked oocytes or all the yolked oocytes are spawned during the spawning season. The most generally held assumption is that all yolked oocytes are potentially capable of developing to maturity. However, in asynchronous species, the phenomena of total and partial resorption are often encountered (Macer 1974), so that the small yolked oocytes could either develop or be resorbed depending on circumstances.

MacGregor (1976) analysed the possible fate of yolked oocytes other than the most advanced mode in four asynchronous species. The ratios of small to intermediate to large yolked oocytes for the four species analysed by MacGregor (*op. cit.*) and for the pilchard were:

Jack mackerel (*Trachurus symmetricus*)	1,6 : 0,0 : 1,0
Pacific mackerel (*Scomber japonicus*)	1,5 : 0,0 : 1,0
Pacific saury (*Cololabis saira*)	10,0 : 1,0 : 1,0
Vinciguerria lucetia	0,0 : 1,0 : 1,0
Pilchard (*Sardinops ocellata*)	0,8 : 1,6 : 1,0

In the Pacific saury and *V. lucetia*, where an intermediate mode of yolked oocytes was present, further evidence for serial spawning was found, but no such evidence was obtained for jack mackerel and Pacific mackerel (MacGregor 1976). This supports the theory that the intermediate mode of yolked oocytes could develop to maturity. However, the fate of the mode of small yolked oocytes is uncertain.

The pilchard off South West Africa clearly exhibits the type of spawning in which the intermediate-mode oocytes can potentially develop to maturity. Spawning in the pilchard takes place from June to April with two peaks (Matthews 1964). The peaks do not occur at the same time each year. Matthews (*op. cit.*) found that they usually occur in August/September and February/March. During the 1972/73 spawning season, heavy concentrations of planktonic eggs were found in November 1972 and March 1973 (King 1974), whereas, during the 1973/74 season, the heaviest concentrations of eggs were in October 1973 and March 1974 with a minor peak in January 1974 (Sea Fisheries Branch, unpublished data).

The presence of two spawning peaks was originally thought to indicate that the pilchard spawned twice within each spawning season. However, the situation is more complex than was first apparent; there are several differences between the two spawning peaks.

King (1977), in discussing egg *distribution*, showed that different major spawning centres corresponded to the two spawning peaks. The winter-spring spawning took place south of Palgrave Point near the coast, whereas in summer-autumn the main spawning took place north of Palgrave Point and further off shore. Spawning was, however, widespread in summer and autumn and it even occurred to some extent south of Palgrave Point. The fish in this study were collected mainly south of Palgrave Point (Fig. 1), so it is possible that the data in this study refer to a specific stock which spawns in the south, regardless of season.

The two spawning centres were also associated with different *temperature* regimes (King 1977, O'Toole 1977). Pilchard larvae hatched from spring-spawned eggs were associated with temperatures of 13-16°C (O'Toole *op. cit.*). In contrast, most of the larvae resulting from eggs spawned during summer and early autumn were found at consistently higher temperature but within wider ranges, and they were most abundant between 18 and 19 °C. From these differences, it would appear that two different spawning groups were involved. This suggestion, however, does not eliminate the possibility that pilchard can spawn twice within a spawning season.

In addition, O'Toole (1977) suggested that the differences between the spawning centres could be related to food production centres. In spring, pilchard spawn predominantly in cold, upwelled water, but during summer and early autumn spawning takes place on the seaward side of the boundary between warm oceanic water and the cooler coastal water. Both these regions are areas of high food production. It is, therefore, not inconceivable that the same stock is spawning twice per season, but each time in the region of high food production.

In this study, an attempt was made at solving the questions about spawning frequency in the pilchard by relating stages of development to mean oocyte volume distribution. It was found that, in early-active ovaries, only one group of yolked oocytes was present. A second mode of yolked oocytes later develop directly from the reserve fund of yolkless oocytes. The two modes of yolked oocytes overlapped at first, but later separated completely as the more advanced mode matured. A third mode of small yolked oocytes sometimes started developing shortly before or after ovulation of the most advanced mode.

On the basis of several generally used criteria, the South West African pilchard has the potential to spawn twice:

(i) A group of yolked oocytes separating from the reserve fund and increasing in size will be spawned in the current spawning season, as has been shown by Hickling and Rutenberg (1936) and MacGregor (1976). Because, in the South West African pilchard, two modes of yolked oocytes separate from the reserve fund, the pilchard is potentially able to spawn twice within a season.

(ii) The presence or absence of yolk has been commonly used in determining whether an oocyte was developing or not (Macer 1974). In *Sardinops ocellata*, the yolked intermediate oocytes can be regarded as developing and, therefore, potentially able to reach maturity.

(iii) Unimodal pilchard ovaries in active and late-active stages, which are found mainly from November to February, may be those in which the most advanced mode has been shed, whereas an additional mode of yolked oocytes has not yet developed.

(iv) In some pilchard ovaries just prior to and after ovulation, the intermediate mode increased in size (Table III).

(v) The pilchard has an extended spawning season and, therefore, there should be sufficient time for more than one batch of yolked oocytes to develop to maturity.

Batch size and total number of oocytes are variable in serial spawners where oocyte resorption and the process of asynchronous development control the number of oocytes during a specific spawning season (Macer 1974). With asynchronous oocyte development, several groups of yolked oocytes develop from the reserve fund of yolkless oocytes during the course of a spawning season. More oocytes may therefore be released in a favourable season (e.g. with abundance of food) than in an unfavourable one.

The rate of oocyte development has not been established for the South West African pilchard. However, some indication may be drawn from studies on other fish. Yamamoto and Yoshioka (1964) found that, in the medaka *Oryzias latipes*, oocytes can develop from the tertiary yolk stage to ripe in about 12 hours. In the pilchard, the tertiary yolk stage could possibly be reached during the late-active stage because, beyond this stage, oocyte dry mass does not increase (Le Clus, in press). However, a histological study should be made to confirm this. If the tertiary yolk stage is reached in late-active fish, the pilchard could spawn shortly afterwards. The intermediate mode, however, would still need to develop from early active to late active

before the next spawning could take place. This development from early active to late active would require the deposition of a considerable quantity of yolk because the dry mass of yolk has to increase at least twofold for the intermediate-mode oocytes to develop into last-mode oocytes (Le Clus *op. cit.*). It is not yet known how long it would take for an ovary to develop from early active to late active, but most of the observations in this report lead to the conclusion that the pilchard could be a serial spawner with the potential to spawn at least twice within a single spawning season.

Important contributions to our knowledge could be made by showing that the oocytes of late-active fish are, in fact, in the tertiary yolk stage, and by establishing the rate of oocyte development either through analysis of gonad maturity and mass or by observations on fish kept in an aquarium. However, local pilchard have not yet been successfully kept in an aquarium.

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LITERATURE CITED

ANDREU, B. and J. DOS SANTOS PINTO 1957 — Características histológicas y biométricas del ovario de sardina (*Sardina pilchardus* Walb) en la maduración, puesta y recuperación. Origen de los ovocitos. *Investigación pesq.* **6**:3-38.

BAIRD, D. 1974 — The biology and the ecology of the South African mackerel, *Scomber japonicus* Houttuyn, and an analysis of the mackerel fishery in South Africa, 1954-1973. Ph.D. thesis, University of Stellenbosch: 241 pp.

BALINSKY, B. I. 1975 — *An Introduction to Embryology. 4th Ed.* Philadelphia; Saunders: 648 pp.

BALL, J. N. 1960 — Reproduction in female bony fishes. *Symp. zool. Soc. Lond.* **1**:105-135.

BOWERS, A. B. and F. G. T. HOLLIDAY 1961 — Histological changes in the gonad associated with the reproductive cycle of the herring *(Clupea harengus* L.). *Mar. Res.* **1961**(5): 16 pp.

CLARK, F. N. 1925 — The life history of *Leuresthes tenuis*, an atherine fish with tide controlled spawning habits. *Fish Bull. Calif.* **10**:51 pp.

CLARK, F. N. 1934 — Maturity of the California sardine (*Sardinops caerulea*) determined by ova diameter measurements. *Fish Bull. Calif.* **42**:49 pp.

DAVIES, D. H. 1956 — The South African pilchard (*Sardinops ocellata*). Sexual maturity and reproduction, 1950-54. *Investl Rep. Div. Fish. S. Afr.* **22**:155 pp.

FOUCHER, R. P. and R. J. BEAMISH 1977 — A review of oocyte development in fishes with special reference to Pacific hake (*Merluccius productus*). *Tech. Rep. nat. mar. Fish. Serv. U.S.* **755**:16 pp.

HARDING, J. P. 1949 — The use of probability paper for the graphical analysis of polymodal frequency distributions. *J. mar. Biol. Ass. U.K.* **28**(1):141-153.

HART, J. L. and J. L. MCHUGH 1944 — The smelts (Osmeridae) of British Columbia. *Bull. Fish. Res. Bd Can.* **64**:27 pp.

HICKLING, C. F. and E. RUTENBERG 1936 — The ovary as an indicator of the spawning period in fishes. *J. mar. biol. Ass. U.K.* **21**(1):311-317.

HILGE, VON V. 1975 — Geschlechsreifung und Laichreifung bei Teleosteern — ein Überblick. *Ber. dt. wiss. Kommn Meeresforsch.* **24**(2-3):172-183.

HUNTER, J. R. and S. R. GOLDBERG — Spawning incidence and batch fecundity in northern anchovy, *Engraulis mordax*. *Fishery Bull. Wash.* **77**(3): (in press).

JALABERT, B. 1976 — In vitro oocyte maturation and ovulation in rainbow trout (*Salmo gairdneri*), northern pike (*Esox lucius*), and goldfish (*Carassius auratus*). *J. Fish. Res. Bd Can.* **33**(4-pt 2):974-988.

KING, D. P. F. 1974 — Pilchard stock estimation by means of egg and larval surveys. Cape Cross Programme (Phase IV), Sea Fish. Brch S.Afr., Internal Report.

KING, D. P. F. 1977 — Distribution and relative abundance of eggs of the South West African pilchard *Sardinops ocellata* and anchovy *Engraulis capensis*, 1971/72. *Fish. Bull. S. Afr.* **9**:23-31.

LE CLUS, F. 1977 — A comparison of four methods used in fecundity determination of the pilchard *Sardinops ocellata*. *Fish. Bull. S. Afr.* **9**:11-15.

LE CLUS, F. — Oocyte mass of the South West African pilchard, *Sardinops ocellata* in relation to oocyte development and spawning period. *Investl Rep. Sea Fish. Brch S. Afr.* **119** (in press).

MACER, C. T. 1974 — The reproductive biology of the horse mackerel *Trachurus trachurus* (L.) in the North Sea and English Channel. *J. Fish. Biol.* **6**(4):415-438.

MACGREGOR, J. S. 1957 — Fecundity of the Pacific sardine (*Sardinops caerulea*). *Fishery Bull. Fish Wildl. Serv. U.S.* **57**(121):427-449.

MACGREGOR, J. S. 1976 — Ovarian development and fecundity of five species of California current fishes. *Rep. Calif. coop. oceanic Fish. Invest.* **18**:181-188.

MATTHEWS, J. P. 1964 — The pilchard of South West Africa (*Sardinops ocellata*). Sexual development, condition factor and reproduction 1957-1960. *Investl Rep. mar. Res. Lab. S.W. Afr.* **10**:96 pp.

O'TOOLE, M. J. 1977 — Investigations into the early life history of the South West African pilchard *Sardinops ocellata* Pappe. In *Investigations into some important fish larvae in the South East Atlantic in relation to the hydrological environment.* Ph.D. thesis, University of Cape Town; Paper 2:53 pp.

SIMMONS, D. C. 1969 — Maturity and spawning of skipjack tuna (*Katsuwonus pelamis*) in the Atlantic Ocean, with comments on nematode infestation of the ovaries. *Spec. scient. Rep. U.S. Fish Wildl. Serv.* **580**:17 pp.

SMITH, S. 1957 — Early development and hatching. In *The Physiology of Fishes* **1**. Brown, M. E. (Ed.). New York; Academic Press: 323-359.

YAMAMOTO, K. 1956 — Studies on the formation of fish

eggs. I. Annual cycle in the development of ovarian eggs in the flounder *Liopsetta obscura*. *J. Fac. Sci. Hokkaido Univ., Ser. 6 Zool.* **12**(3):362-371.

YAMAMOTO, K. and F. YAMAZAKI 1961 — Rhythm of development in the oocyte of the Gold-fish *Carassius auratus*. *Bull. Fac. Fish. Hokkaido Univ.* **12**(2):93-110 + 2 plates.

YAMAMOTO, K. and H. YOSHIOKA 1964 — Rhythm of development in the oocyte of the médaka, *Oryzias latipes*. *Bull. Fac. Fish. Hokkaido Univ.* **15**(1):5-19.

Fish. Bull. S. Afr. 12:69—74
1979

RECOVERY OF A POPULATION OF WHITE MUSSELS *DONAX SERRA* AT ELANDS BAY, SOUTH AFRICA, FOLLOWING A MASS MORTALITY

G. DE VILLIERS

In December 1966 a population of the white mussel *Donax serra*, a popular bait organism, suffered a severe mass mortality at Elands Bay on the west coast of South Africa after a red-tide bloom that involved the dinoflagellate *Gonyaulax grindleyi*. The initial response of the white-mussel population was investigated and regular surveys to monitor the recovery have continued. Full recovery is likely to require approximately 14 years. At reduced population levels, a fairly definite quantitative parent-stock/recruitment relationship existed but apparently vanished after recovery to higher population levels. Peak settlements by recruits on the beach did not always occur at the same time of year.

In Desember 1966 is 'n bevolking van die witmossel *Donax serra*, 'n gewilde aasorganisme, deur 'n ernstige massavrekte by Elandsbaai aan die weskus van Suid-Afrika getref ná 'n rooiwateropbloei waarby die dinoflagellaat *Gonyaulax grindleyi* betrokke was. Die aanvanklike reaksie van die witmosselbevolking is ondersoek en gereelde opnames om die herstel dop te hou, is sedertdien voortgesit. Volkome herstel sal waarskynlik altesaam omtrent 14 jaar duur. By verminderde stapelgroottes het 'n taamlik duidelike kwantitatiewe verband tussen moederbevolking en rekrutering bestaan, maar dit het blykbaar verdwyn nadat herstel tot by hoër bevolkingsvlakke gevorder het. Die hoofvestiging van rekrute op die strand het nie altyd op dieselfde tyd van die jaar geskied nie.

Because of the popularity of white mussels *Donax serra* as bait for anglers and the consequent intensive exploitation by private and commercial bait collectors, routine population surveys were initiated in 1966 on a number of selected beaches in the Western Cape. These surveys provided material for certain biological studies, the results of which were published by De Villiers (1973, 1974). Research has also been conducted in the Eastern Cape on the same species (Hanekom 1975).

At Elands Bay (Fig. 1) surveys were conducted in July and October 1966 shortly before a mass mortality in December 1966. A special survey at the time revealed that a bloom of the hitherto unknown dinoflagellate *Gonyaulax grindleyi*, which was later described by Reinecke (1967), was apparently responsible for the mortality (Grindley and Nel 1970). De Villiers (1974) quantitatively described the extent of the mortality and gave an account of the initial response of the white-mussel population. Annual surveys aimed at monitoring the state of the white-mussel population continued after the initial report was published.

This report documents the recovery of the Elands Bay *Donax* population and illustrates certain interesting features of the recovery process.

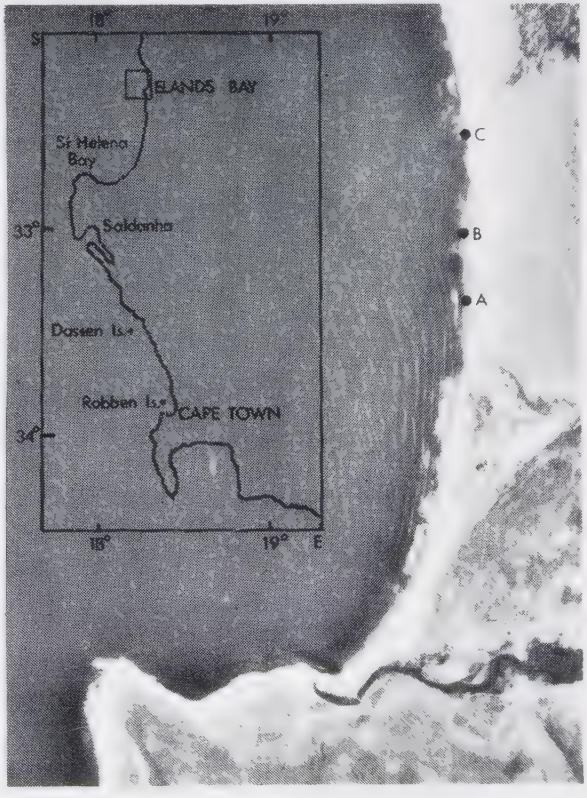

Fig. 1: Survey area and sampling sites (A, B and C)

METHODS

As on most beaches on the west coast of South

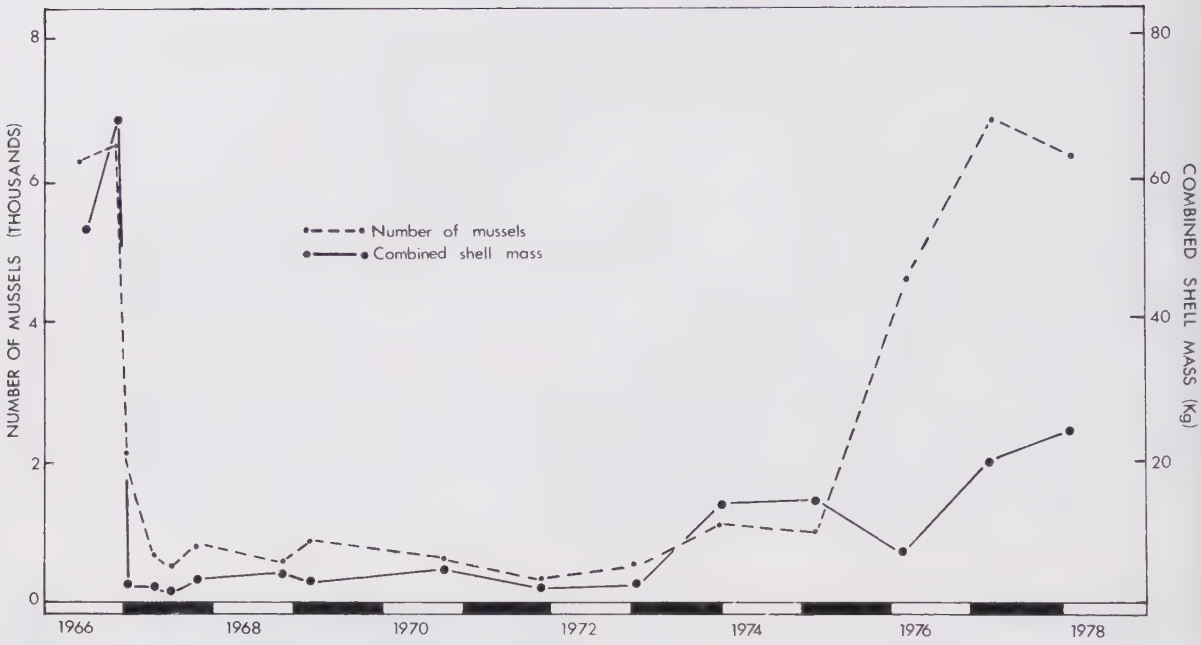

Fig. 2: Relative population size in terms of numbers and biomass (shell mass) of white mussels found in three transects combined

Africa, white mussels at Elands Bay were found to vary in size according to their position within the intertidal zone. Very small mussels occurred high up on the beach, whereas adults were distributed around and even below the mean-spring-low-water mark (De Villiers 1974).

Surveys were conducted during spring low tides to monitor the size composition and relative abundance of white mussels. During all surveys, 25-cm-wide transects, starting well within the surf zone and extending landwards throughout the range of mussel occurrence and normally ending near the high-water mark, were investigated by scooping out and sieving all sand down to the maximum depth to which mussels burrow (usually <25 cm deep). All mussels $\geq 2{,}5$-mm shell width within the transect were collected and sorted into 2,5-mm shell-width size classes.

At Elands Bay, three such transects were investigated at fixed positions during each survey (Fig. 1). Surveys were initially conducted every three months, but later on an annual basis.

A more detailed account of sampling procedures and techniques is given by De Villiers (1973).

RESULTS

De Villiers (1974) showed that different sizes of white mussel were affected to a differing extent by the dinoflagellates, presumably because of horizontal stratification according to size on the beach. Larger mussels lower down the beach suffered the full impact of the bloom, whereas juveniles higher up were less affected, apparently because of diminished exposure to the dinoflagellates. As a result, the population structure that existed prior to the mass mortality changed drastically, the older generations being virtually obliterated but the younger surviving to a greater degree. De Villiers (*op. cit.*) maintained that the generation gap caused by this differential mortality of size classes persisted for a number of years.

Figure 2 provides a summary of the relative numbers and biomass of mussels that populated the beach on the various sampling dates during the survey period. It is evident that the relative number of mussels had increased substantially from the end of 1974, and by 1977 had reached the levels

that existed before the mortality. However, the biomass had not yet recovered to the same extent, simply because the average size of mussels during the last two surveys was still much less than that during 1966.

Differences in the size composition of the population on the various sampling dates can be assessed from Figure 3, which depicts the successive generations by successive letters of the alphabet and is an updated version of Figure 20 of De Villiers (1974). The adult section of the population (i.e. mussels with shell width ≥ 35 mm — De Villiers 1973) has been shaded for easy distinction. The almost complete disappearance of large mussels (generations a and b) and the persistence of a generation gap (the poorly represented generations e and f) can clearly be detected from Figure 3.

Apart from the obvious difference in the average size of mussels on the first two and last two surveys, Figure 3 reveals that the settlement and survival of three strong year-classes (n, o and p), as well as of a fourth weaker one (m), during the period 1975 — 1978, accounted for the most recent increase in numbers.

The concept of a relationship between parent stock size and associated recruitment, as suggested by De Villiers (1974), originated in the timing of the attainment of sexual maturity by generations c and d and the arrival of the strong year-class g (Fig. 3, surveys on 24/10/68 and 18/2/69). When generation g became sexually mature, yet another strong year-class, j, made its appearance (Fig. 3, survey on 3/11/71). This trend was reconfirmed when the final recovery stage commenced fairly soon after year-class j had become sexually mature.

Therefore, and despite the crudeness of the survey results, an attempt was made to relate parent stock size in terms of shell mass (biomass) to recruitment in terms of numbers on a common time axis (Fig. 4). The relative parent stock size at the time of each survey was calculated by totalling the product of average shell mass and the frequency per size class for mussels with shell width ≥ 35 mm. Shell mass was chosen as a relative index of biomass because it is more suitable than round mass, which is subject to seasonal change.

The number of recruits per generation was obtained by adding, from the most relevant survey, the number of mussels within the respective size classes that constituted it (e.g. population strength of generation p = sum of mussels within shell-width range from 0 to 20 mm — Fig. 3, survey dated 21/2/78). The mean date of arrival on the beach (settlement) of any new generation was then estimated by considering the sampling date, average size and growth rate.

Figure 4 reflects the close relationship between the relative success of recruitment and the prevailing parent stock size between 1967 and early 1973. Later in 1973 and during 1974, there was no immediate response in recruitment to the sudden surge in parent stock biomass, but such a response came early in 1975. During 1976 and 1977, parent stock biomass was lower, but nevertheless remained higher than during the period 1967-1972. Recruitment, however, remained extremely good after 1975, in spite of the fluctuation in parent stock.

DISCUSSION

From Figure 4, it may be concluded that a fairly close relationship had existed between parent stock size and recruitment while the adult stock was depleted, but when the adult stock had recovered to a certain size, the relationship apparently vanished. An explanation for such a phenomenon could be that recruitment depends on several factors. When the adult stock is small, the volume of reproductive material released by the adult population would appear to be the determining factor for recruitment success. Beyond a certain adult stock size, however, the volume of reproductive material released is not a limiting factor, and some of the other factors, e.g. changes in the environment, dictate recruitment success. Consequently the relationship vanishes. De Villiers (1974) suggested that the relationship between parent stock size and recruitment indicates that, in the case of Elands Bay, the white-mussel population is primarily dependent on itself for its own reproduction. The nearest large population of *D. serra* is situated at Paternoster, 40 nautical miles south of Elands Bay. Occasional surveys at Paternoster have shown that recruitment was adequate and that a large adult population existed during the period 1966-1969 (De Villiers *op. cit.*), but that by February 1978 the population had decreased substantially for reasons unknown. It is thus evident that the welfare of the Paternoster population bore no relation to that of the one at Elands Bay during the same period, and that the populations are apparently isolated from each other.

Therefore, larval dispersion could not have been very great, even though it has been shown by Coe (1955) and Wade (1968) that the planktonic larval stage for *Donax* spp. may last for three weeks or more. However, both these authors found that this self-dependence certainly does not always exist

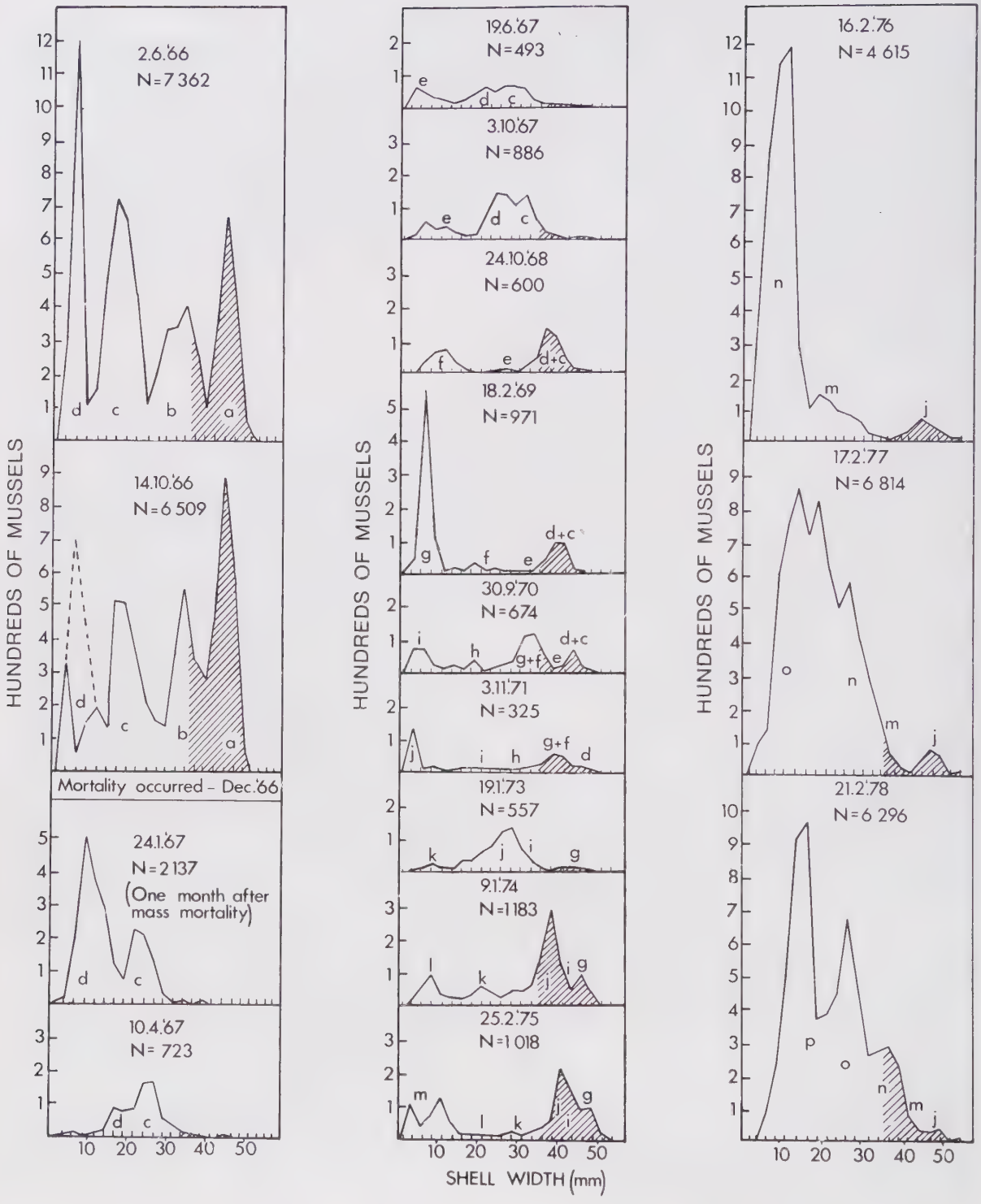

Fig. 3: Size frequency distribution of mussels found in three transects combined

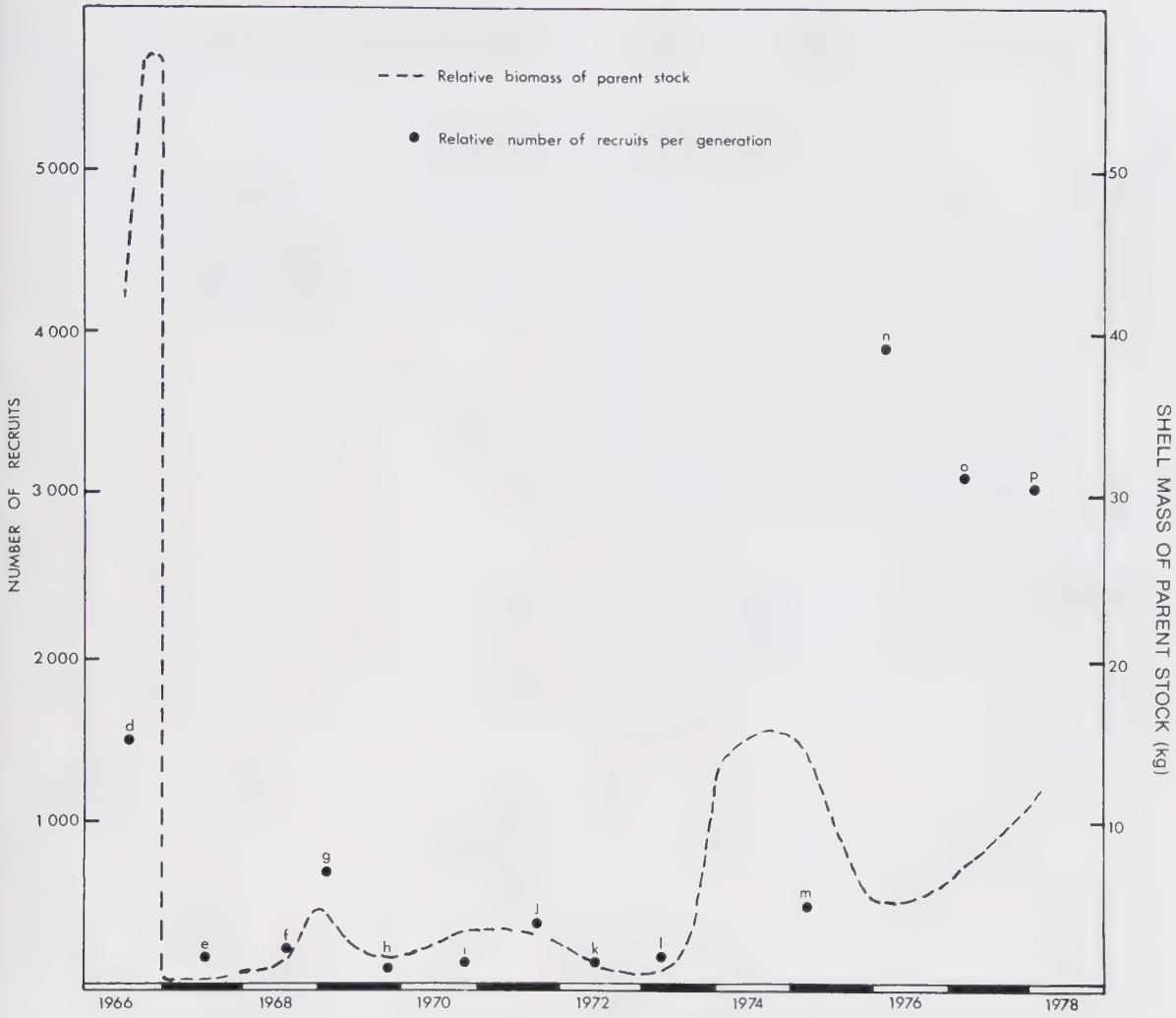

Fig. 4: Parent stock size and recruitment success during the survey period

amongst *Donax* populations and, depending on local conditions, variation in this regard could be expected amongst different *D. serra* populations along the South African coast.

In respect of environmental influences, it is interesting to note that peak settlement on the beach did not always occur in the same season. Figure 3 provides a few examples. In February 1969, the modal size of the youngest generation (g) was 6,3 mm, whereas on virtually the same day in 1978, that of generation p was 16,3 mm. Furthermore, surveys conducted on 16/2/76 and 17/2/77 indicate that continuous settlement at a high rate was experienced throughout 1976. These observations substantiate the conclusions reached by De Villiers (1973), who stated that spawning seasons are not clearly defined and that variations may be expected from year to year.

The information reflected in Figure 4, and to a lesser extent in Figure 3, indicates that generations d, g, j and m can be singled out as the more successful ones during the period 1966-1975. Each of these generations, except m, were followed by *two* less successful settlements. Bearing in mind that, during the mass mortality, *two* conspicuous cohorts (a and b) suffered almost complete extinc-

tion, this observation once again illustrates the perennial influence of the size-related mortality.

From the information presented in Figure 2, it could be argued that the population at the time of the last survey (1978) had not yet fully recovered, because the relative biomass had only returned to approximately 37 per cent of the level prior to the mass mortality. However, at established growth and mortality rates (De Villiers 1974), and without taking any further settlement into consideration, the relative population biomass could be expected to reach approximately 57 per cent and 61 per cent of the October 1966 level in February 1979 and February 1980 respectively. Extrapolation beyond February 1980 indicates that any additional increase in relative biomass will only occur if appreciable settlement is experienced. The biomass level in February 1978 should nevertheless be maintained until 1982, even if future settlement fails to materialize, which means that the recovering population already possesses a substantial degree of resilience.

If recruitment continues at about the same rate as in 1977/78, the population could be fully recovered by 1981 and, because this is most likely to be the case, it may be concluded that the population has entered the final stage of recovery. Full recovery of the population will therefore have taken approximately 14 years.

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LITERATURE CITED

COE, W. R. 1955 — Ecology of the bean clam, *Donax gouldi*, on the coast of Southern California. *Ecology* **36**(3):512-514.

DE VILLIERS, G. 1973 — Reproduction of the white sand mussel *Donax serra* Röding. *Investl Rep. Sea Fish. Brch S. Afr.* **102**:33 pp. (published in English in 1975).

DE VILLIERS, G. 1974 — Growth, population dynamics, a mass mortality and arrangement of white sand mussels, *Donax serra* Röding, on beaches in the South-Western Cape Province. *Investl Rep. Sea Fish. Brch S. Afr.* **109**:31 pp. (published in English in 1975).

GRINDLEY, J. R. and E. A. NEL 1970 — Red water and mussel poisoning at Elands Bay, December 1966. *Fish. Bull. S. Afr.* **6**:36-55.

HANEKOM, N. 1975 — A study of *Donax serra* in the Eastern Cape. M.Sc. thesis, University of Port Elizabeth: 70 pp.

REINECKE, P. 1967 — *Gonyaulax grindleyi* sp. nov. A dinoflagellate causing a red tide at Elands Bay, Cape Province in December 1966. *Jl S. Afr. Bot.* **33**(3):157-160.

WADE, B. A. 1968 — Studies on the biology of the West Indian beach clam, *Donax denticulatus* Linné. 2. Life history. *Bull. mar. Sci. Gulf Caribb.* **18**(4):876-901.

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1979

TRAP SELECTIVITY AND SEASONAL CATCHABILITY OF ROCK LOBSTER *JASUS LALANDII* AT ROBBEN ISLAND SANCTUARY, NEAR CAPE TOWN

D. E. POLLOCK and C. J. DE B. BEYERS

Comparison of diver- and trap-caught rock lobsters at Robben Island showed fewer small animals in trap catches than in the population. The sex ratio of rock lobsters in trap catches was affected by the moulting cycles of males and females. Catchability of males was low during their peak months of moulting (November and December) but, during at least the first two months thereafter, males were more catchable than females of the same size range. This biased the sex ratio in trap catches towards males, a feature which intensified further in April when females commenced moulting and ceased to feed.

Vergelykings tussen duiker- en fuikvangste te Robbeneiland het aangetoon dat daar minder klein kreef in fuikvangste as in die populasie aanwesig was. Die geslagsverhouding van kreef in fuikvangste is deur die verdoppingsiklusse van mannetjie- en wyfiekreef beïnvloed. Die vangbaarheid van mannetjies was laag wanneer hul verdopping op sy hoogste was (November en Desember), maar gedurende ten minste die eerste twee maande daarna was mannetjies vangbaarder as wyfies van dieselfde groottebestek. Dit het die geslagsverhouding in fuikvangste ten opsigte van mannetjiekreef bevooroordeel en is verder in April beklemtoon met die aanvang van die verdoppingsiklus by wyfies en die gevolglike staking van voeding.

Both traps and hoopnets are widely used in the fishery for rock lobster *Jasus lalandii* off the West Coast. Traps, however, have become increasingly important in recent years owing to their greater efficiency (Newman and Pollock 1969). A survey was made to determine whether seasonal variations in catchability of rock lobsters of different size and sex were reflected in trap catches. This would be of value in determining whether size composition and sex ratios from sampled commercial trap catches give a realistic indication of the size composition and the sex composition at any time of the year.

In the present survey, a monthly trap-fishing and diving programme was conducted near Cape Town in a rock-lobster sanctuary at Robben Island, in an area where large numbers of legal-sized rock lobsters (>8,9 cm carapace length) occurred. Sampling by the non-selective method of diving allowed comparisons to be made between trap catch composition and the population structure in the study area.

METHODS

Variations in sex ratio and size composition were known to occur at times in certain areas at Robben Island, so that care was taken to ensure that divers sampled the population in the immediate vicinity of the traps. Seven baited traps were used, spaced at 37-m intervals on a longline which was buoyed at each end. The metal-framed rectangular traps measuring 135 cm × 86 cm × 53 cm were covered with netting with a stretched mesh size of 6,2 cm. These traps were identical to those used by commercial fishing vessels.

The traps were set overnight and on the following day a pair of divers descended at each end of the longline, each diver collecting randomly a total of at least 45 rock lobsters in between the traps. From observations made, it was assumed that the effective range of influence of the bait extended no further than 12 m away from the trap, and the longline was marked at 12 m on either side of each trap. No rock lobsters were collected within the 12-m radius of each trap, in case size composition and sex ratio had been altered by the entry of more-actively foraging individuals into the traps.

Care was taken to ensure that divers' samples were unbiased. Fortunately, few inaccessible caves and crevices were present in the study area, and the first 40-50 rock lobsters seen irrespective of size or sex constituted a random sample.

The traps were set during one week in each month at a depth of 14 m, west of Robben Island. Although this side of the island is greatly exposed to prevailing south-westerly swells, rock lobsters are extremely abundant, and kelps relatively sparse. These factors facilitated the collection of large samples of rock lobsters by diving, for comparison with trap catches. The divers' sample (400-600 animals) was usually collected within one day unlike fishing with traps which had to be repeated on consecutive overnight sets until sufficient numbers had been caught for comparison.

RESULTS

The experiment ran from November 1976 to April 1977 and again from November 1977 to March 1978. The period November to March/April encompasses most of the open season for commercial fishing (November to June). More than 80 per cent of the commercial catch is taken between November and February, so that observations made during the months of research were considered adequate to explain trends during the commercial fishing season.

Owing to the relatively shallow depth in which work took place, trap catches were greatly influenced by swell and wave action. Daily fluctuations in swell height caused marked variation in catches, and no clear pattern of catch per unit effort emerged during the two study periods. Catches were generally better when calm seas prevailed, for the resultant lack of bottom surge presumably allowed greater freedom of movement for foraging animals. Bad weather prevented sampling in December 1977, whereas on one occasion in February 1977, trap catches were lost to poachers.

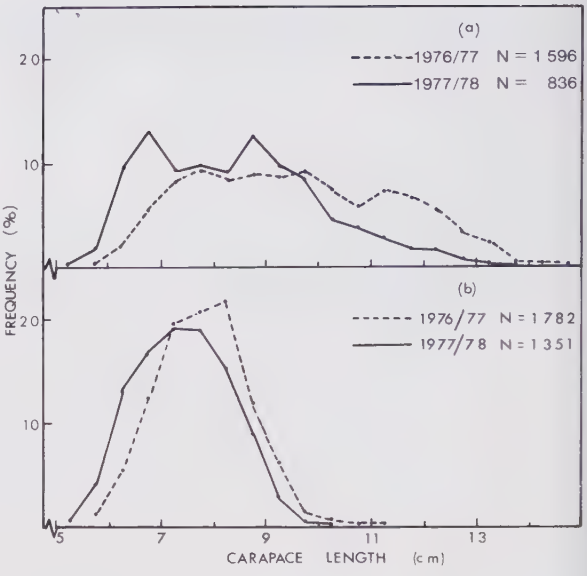

Fig. 1: Size frequency distributions from divers' catches of male (a) and female (b) rock lobsters at 14-m depth off Robben Island during two seasons

Size composition of divers' catches

The size frequency distribution in divers' catches was considered to be more representative of the population than that in trap catches and, therefore, only rock lobsters caught by diving are considered in this section. The percentage frequency distributions of males and females for the two seasons are shown in Figure 1. There appeared to be a larger proportion of animals smaller than 7-cm carapace length in the research area during 1977/78 than during 1976/77. This applied to both sexes.

From Figure 1, it is also apparent that few animals smaller than 6 cm were present in the study area (14 m deep). This is a characteristic feature of the mid- and deep-water rock-lobster grounds, because juveniles are located only in shallow waters, usually close inshore. Recruitment of small animals to stocks further off shore takes place by gradual emigration to deeper waters (Pollock 1973).

Comparison of divers' and trap catches

Size composition — For comparison, size compositions for each season and sex separately are shown in Figures 2 and 3. Both figures show similar size frequency distributions of divers' and trap catches, although there appear to be relatively fewer small animals (less than about 8-cm carapace length) in trap catches than in divers' catches. This trend appears consistently for both sexes in each of the seasonal results.

Sex ratios — Sex ratios were examined initially for each size class in divers' and trap catches, and compared. Owing to the very small numbers of 6,0-6,9 cm animals in both divers' and trap catches, and to the lack of females larger than 10 cm (carapace length), sex ratio data for animals smaller than 7 cm and larger than 10 cm had to be excluded. Sex ratios in the 7 cm, 8 cm and 9 cm size classes (all sexually mature animals) showed the same trends, so that data for these size classes were combined. Results are presented in Table I for each month during the two seasons, sex ratio being expressed as the percentage of males only. The table shows that fewer males than females entered traps in November and December, whereas in ensuing months a reversal of this trend took place. Low catchability of males by traps in November and December was associated with a high incidence of moulting. This is shown by the high percentage of soft-shelled males in immediate premoult (SO) and postmoult (SN) shell states in these months. The

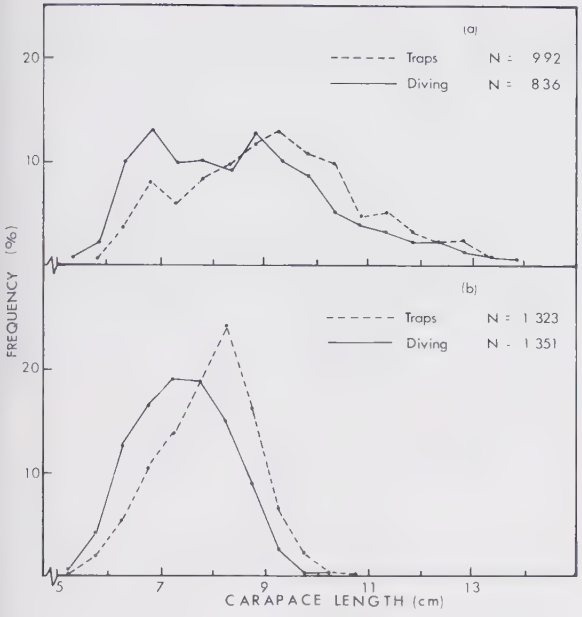

Fig. 2: Size frequency distributions of male (a) and female (b) rock lobsters caught by traps and divers at Robben Island, 1976/77

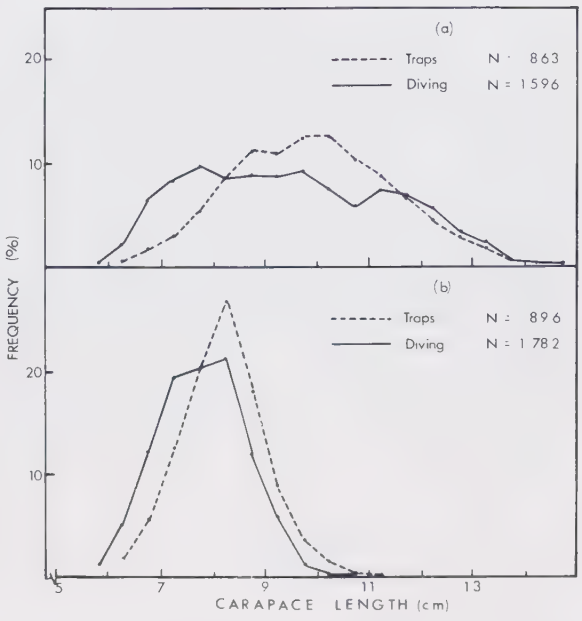

Fig. 3: Size frequency distributions of male (a) and female (b) rock lobsters caught by traps and divers at Robben Island, 1977/78

definition of shell state is the same as that of Heydorn (1969a). Earlier studies by Heydorn (*op. cit.*) and Pollock (1978) have confirmed that peak moulting of males occurs during November and December at Robben Island. The difference in sex ratios between divers' and trap catches was significant at

Table I: Comparison of sex ratios in monthly samples taken by divers and traps in relation to carapace state (7,0 — 9,9 cm size classes combined)

Season and month	Percentage of males		*P*	Shell categories in divers' catch (%)	
	Divers	Traps		Males SO + SN	Females HO + SO + SN
1976/77					
November	45 (409)*	17 (327)*	$<0{,}005$	11	0
December	49 (453)	24 (397)	$<0{,}005$	20	<1
January	21 (715)	46 (166)	$<0{,}005$	<1	0
February	38 (111)	—	—	2	0
March	42 (310)	47 (347)	$0{,}1 > P > 0{,}05$	<1	0
April	45 (376)	82 (143)	$<0{,}005$	3	11
1977/78					
November	41 (329)	21 (765)	$<0{,}005$	2	0
December	—	—	—	—	—
January	22 (391)	36 (426)	$<0{,}005$	5	2
February	42 (335)	65 (228)	$<0{,}005$	0	5
March	40 (324)	56 (174)	$<0{,}005$	0	0

*Sample sizes in parenthesis

the 0,5-per-cent level for all months except March 1977. In April 1977, the proportion of males entering traps increased sharply, coinciding with a rise in moulting activity by females. The latter is shown by the high percentage of females in near premoult (HO, SO) and immediate postmoult (SN) shell states. Feeding of rock lobsters ceases prior to and immediately after moulting.

It is interesting to note that the true sex ratio in the population (column 1 of Table I), as determined from divers' catches, usually varied between 38 per cent and 49 per cent males, but in January of both seasons this dropped to 21 per cent and 22 per cent respectively, signifying a change in the relative abundance of the sexes in the study area. This could have been the result of an influx of females into the area, or conversely, of an emigration of males.

DISCUSSION

Comparison of the size composition of divers' and trap catches showed that relatively few small individuals entered the traps, so that the proportion of animals larger than the modal size was higher in trap catches than appeared in the population. The relative scarcity of small individuals in the traps could be partly explained by escape of small animals through the mesh, although this should have affected animals smaller than 7 cm to the greatest extent. Heydorn (1969b) noted that smaller animals were sometimes kept away from the bait by the aggressive behaviour of larger animals. In this survey, however, this was not considered as a reason for the scarcity of small animals because traps were used rather than hoopnets and, in traps, the catchability is unlikely to be affected by such behaviour. An examination of moulting frequency per month of the smallest size classes of males and females showed a similar frequency to that observed in larger animals, and it was concluded that the apparent reduced catchability of small males and females throughout the study periods was not related to differing moulting cycles. It is possible that foraging behaviour of small animals was affected by surge to a greater extent than that of larger animals.

Owing to the reduced proportion of small animals in trap catches and the resultant relative increase in proportion of larger animals, the results of the present study did not substantiate earlier findings by Newman and Pollock (1974), who noted that large animals (especially males) were less catchable by traps than smaller individuals, an observation which was substantiated by tag-return results.

Comparison of sex ratios in the present study showed that male catchability was depressed during moulting (in November and December), as a result of the cessation of feeding and foraging activity just prior to and after moulting. This was followed by a marked increase in male catchability compared to that of females of the same size for at least the following two months (January and February). This is not surprising, for males would be expected to feed actively after their shells had hardened sufficiently. Females at this stage would still be in the intermoult phase, and their catchability would not be expected to be affected in any way. In April, the female moulting cycle commences, and the proportion of males in trap catches underwent a further increase.

On West Coast fishing grounds, highest catch rates are invariably experienced in the early part of the season, when catches are composed largely of recently moulted, male rock lobsters. A marked seasonal decline of catch per unit effort is normal but is greater than that predicted from mortality rates alone (Newman and Pollock 1971, 1974; Pollock 1978). This suggests that a decline in catchability takes place during the season, or rather that catch rates are boosted to an artificially high level shortly after peak moulting of males has taken place. This explains why, at Dassen Island and the Cape Peninsula where peak male moulting occurs in November and December, highest catch rates are usually experienced in December and January. On fishing grounds further north, peak moulting occurs earlier — in October in the Lambert's Bay region (Pollock *op. cit.*). Here catch rates are normally maximal in November at the commencement of the fishing season.

The results of the present study suggest that sex ratios in commercial trap catches will be biased towards males, especially during the first month or two after peak moulting of males has taken place. This feature will be intensified during April and May when females are moulting. On the southern fishing grounds of Dassen Island, the Cape Peninsula and at Robben Island, where peak moulting of males takes place in November and December, the proportion of males in trap catches during these months is likely to be lower than in the actual populations. These research findings are substantiated by commercial catch data.

ACKNOWLEDGEMENTS

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comments and criticism. Also, Miss F. le Clus is acknowledged for her help in the statistical analysis.

LITERATURE CITED

HEYDORN, A. E. F. 1969a — The rock lobster of the South African west coast *Jasus lalandii* (H. Milne-Edwards). 2. Population studies, behaviour, reproduction, moulting, growth and migration. *Investl Rep. Div. Sea Fish. S. Afr.* **71**:52 pp.

HEYDORN, A. E. F. 1969b — The South Atlantic rock-lobster *Jasus tristani* at Vema Seamount, Gough Island and Tristan da Cunha. *Investl Rep. Div. Sea Fish. S. Afr.* **73**:20 pp.

NEWMAN, G. G. and D. E. POLLOCK 1969 — The efficiency of rock lobster fishing gear. *S. Afr. Shipp. News Fishg Ind. Rev.* **24**(6):79, 81.

NEWMAN, G. G. and D. E. POLLOCK 1971 — Biology and migration of rock lobster *Jasus lalandii* and their effect on availability at Elands Bay, South Africa. *Investl Rep. Div. Sea Fish. S. Afr.* **94**:24 pp.

NEWMAN, G. G. and D. E. POLLOCK 1974 — Biological cycles, maturity and availability of rock lobster *Jasus lalandii* on two South African fishing grounds. *Investl Rep. Sea Fish. Brch S. Afr.* **107**:16 pp.

POLLOCK, D. E. 1973 — Growth of juvenile rock lobster *Jasus lalandii*. *Investl Rep. Sea Fish. Brch S. Afr.* **106**:16 pp.

POLLOCK, D. E. 1978 — Growth and production rates of the rock lobster *Jasus lalandii* (H. Milne-Edwards). Ph.D. thesis, University of the Witwatersrand: 226 pp.

Fish. Bull. S. Afr. 12:80—84
80 *1979*

A RELATIONSHIP BETWEEN SEA SURFACE TEMPERATURE VARIABILITY AND ANCHOVY *ENGRAULIS CAPENSIS* RECRUITMENT OFF SOUTH WEST AFRICA, 1970-1978

A. J. BOYD

A negative correlation with coefficient of −0,93 between the surface temperature variability with time during a spawning season and the resultant recruitment of the South West African anchovy *Engraulis capensis* is presented. This correlation permits rough prediction of recruitment prior to the fishing season and it is shown to be not particularly sensitive to area or time limitations. It is argued that the larval stage is that at which environmental conditions are crucial to recruitment levels, and surface temperature variability is thus linked with larval survival.

'n Negatiewe korrelasie met koëffisiënt van −0,93 is gevind tussen oppervlaktemperatuurwisselvalligheid t.o.v. tyd, gedurende 'n kuitskietseisoen, en die resulterende rekrutering van die Suidwes-Afrikaanse ansjovis *Engraulis capensis*. Hierdie korrelasie maak dit moontlik om 'n benaderde voorspelling van rekrutering voor die visvangseisoen te maak; dit blyk ook nie besonder gevoelig vir gebieds- en tydsbeperkings te wees nie. Daar word aangevoer dat dit gedurende die larwale stadium is dat omgewingsfaktore die uiteindelike rekruteringsvlakke beslissend beïnvloed en daarom kan oppervlaktemperatuurwisselvalligheid met larwale oorlewing in verband gebring word.

Because recruitment of the South West African anchovy *Engraulis capensis* does not appear to depend significantly on parent stock size (Butterworth and Le Clus 1979), an attempt was made to identify an environmental indicator having a statistically significant relationship with anchovy recruitment, that is 0+ year-class strength. The only environmental parameter with sufficient data continuity and a wide enough geographic area of coverage to be used as an indicator was sea surface temperature.

DATA SOURCES

South African Maritime Command produces a surface temperature chart for the West Coast every 10 days using data received from shipping. The charts were digitized at the Sea Fisheries Branch and average temperature values for different areas, and combinations of these areas, were calculated. The areas are shown in Figure 1. The project is known as the South West African Surface Temperature Project (SWASTP) and its output has been validated by comparison with direct measurements made by the Branch. Part of this validation consisted of comparing 220 surface temperatures measured on board research craft with corresponding values obtained from the charts. The mean difference was found to be 0,07°C and the standard deviation of individual differences was 1,41°C. Thus, if an average is obtained from 27 extracted values, as are the averages used in this study, the standard error of the mean would be 0,27°C (1,41/$\sqrt{27}$), and

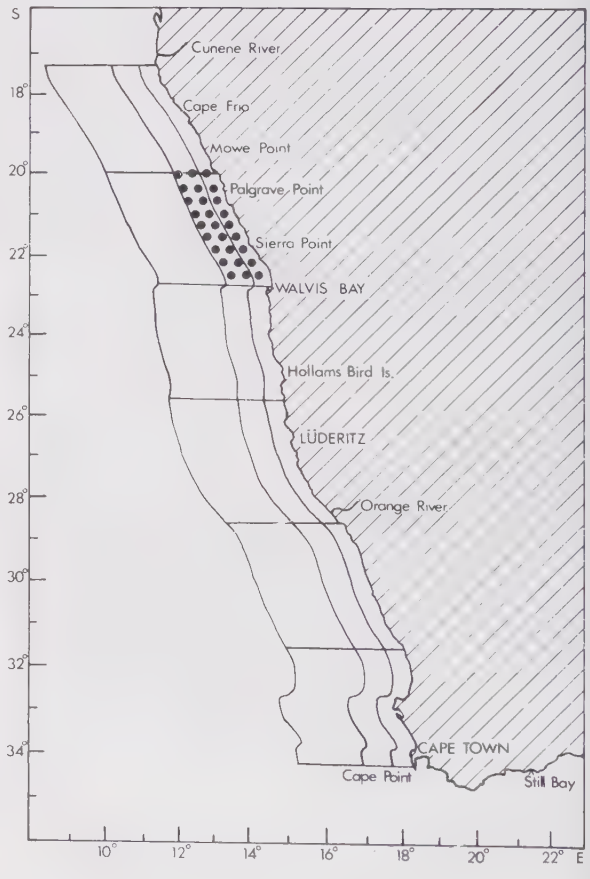

Fig. 1: Routine SWASTP areas of spatial averaging (dots mark the digitization grid used in this study)

the bias 0,07°C. This is felt to be acceptable, considering the accuracy of the biological data used.

The anchovy recruitment figures calculated from catch statistics by means of Virtual Population Analysis (VPA) are from Butterworth and Le Clus (1979). Data from 1970 to 1978 are used, but the period over which the VPA estimates are considered reliable is 1970-1977. The lower limit of the 0+ year-class as determined from numbers of the class actually caught proves that recruitment was better in 1978 than the average of VPA recruitment estimates for the period 1970-1977. Hence this lower limit can be considered reliable for 1978.

METHODS AND RESULTS

The temperature averages from the routine output of SWASTP to which most attention was paid in this investigation were those from areas covering the known anchovy spawning grounds deduced from egg and larva distributions (King 1977, O'Toole 1977). These authors found that most spawning took place within 60 nautical miles of the coast, though their studies showed that the northern and southern limits of spawning could vary radically from one year to the next. The main spawning season was found to lie between December and April.

With the above information restricting the temporal and spatial bounds of the SWASTP temperature output that could be used as a physically justifiable indicator of anchovy recruitment, both temperature and different formulations of temperature variability were correlated against anchovy recruitment on a yearly basis.

The only markedly successful correlation was between the standard deviation of a temperature time series for each spawning season and the recruitment resulting from the spawning season, for the years 1970-1978. This correlation will be shown to be not particularly sensitive to area limitations or to the months included in the spawning season.

The correlation between surface temperature variability and anchovy recruitment is presented in Figure 2, and the data are tabulated in Table I. The temperature data source is SWASTP output from the area shown in Figure 1. The northern and southern limits of this area were simultaneously varied to optimize the correlation shown in Figure 2, because of the vagueness of these limits from the egg and larva distributions. The correlation was not very sensitive to this variation; this is shown in Figure 3.

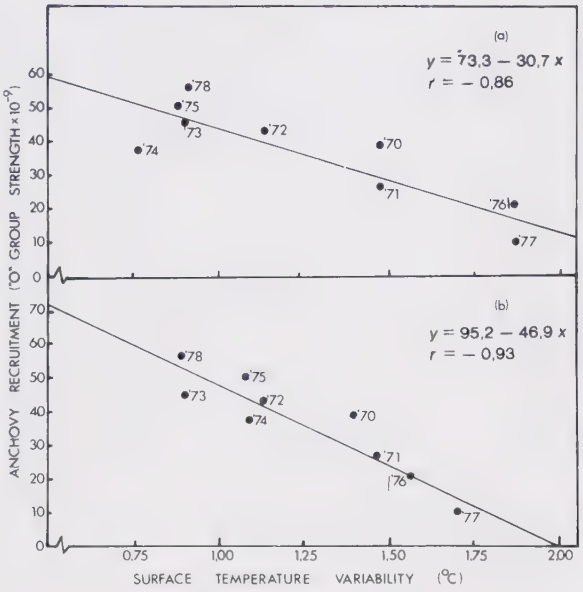

Fig. 2: The relationship between anchovy recruitment and surface temperature variability
a) over 3 months,
b) over 5 months,
(r = correlation coefficient)

The off-shore limit of the area was not varied to optimize the correlation because this demarcation of the spawning grounds is thought to be reasonable, and because of temperature data considerations: namely, having sufficient grid points contributing to each average on the one hand, and not obscuring valid differences by over-averaging on the other.

The correlation's lack of sensitivity on the time definition of the spawning season can be seen by comparing Figures 2a and 2b and noting that the correlation coefficient only falls from −0,93 to −0,86, if the spawning season considered is only from December to February. No optimization of the temporal aspect was attempted. Omitting February data does, however, upset the correlation because January and February are normally the peak spawning months. The December-February correlation shown in Figure 2a has special value in that it permits a rough prediction of anchovy recruitment to be made for the forthcoming season, before the commercial fishing season starts in March or April.

Table I: Temperature and recruitment data

Month	Temperature (°C)								
	1969/70	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78
December	16,2	16,5	16,9	18,8	18,5	16,9	15,5	15,8	16,3
	16,1	14,6	16,8	18,6	17,6	17,1	15,4		18,4
	16,1	16,3	17,1	19,1	18,1	16,5	15,4	17,4	18,1
January	16,1	17,3	19,9	17,7	18,3	17,4	16,4	16,2	16,6
	17,7	17,8	18,6	17,3	19,6	16,6	17,5	17,3	17,7
	18,9	17,9	18,3	17,7	19,9	16,5	19,3	20,1	18,0
February	18,9	19,2	18,8	17,7	19,2	18,0	20,3	16,8	18,9
	19,1	19,3	19,0	19,6	19,2	17,7	18,8	19,7	18,8
	19,3	17,8	17,0	19,7	19,2	19,2	18,9	20,6	18,3
March	17,4	17,8	19,6	18,7	20,7	19,7	17,9	19,6	18,6
	17,9	17,3	19,2	18,7	21,2	17,2	17,7	18,0	18,2
	17,1	18,0	18,8	18,0	18,6	19,3	19,4	17,5	17,6
April	16,7	15,3	17,8	16,8	17,2	18,4	17,2	15,9	17,0
	15,0	14,9	17,3	17,0	18,2	18,2	16,3	18,0	18,2
	15,5	15,6	16,4	17,7	19,2	16,6	16,9	15,4	16,1
* S1	1,47	1,47	1,13	0,90	0,76	0,88	1,90	1,87	0,91
** S2	1,39	1,46	1,13	0,90	1,09	1,08	1,57	1,70	0,89
Recruitment †	38,9	26,5	43,4	45,8	37,5	50,8	21,1	10,1	56,3

* S1 is the standard deviation of the 9 temperature averages from December to February inclusive
** S2 is the standard deviation of the 15 temperature averages from December to April inclusive
† Recruitment is expressed in 0+ year-class strength $\times 10^{-9}$

DISCUSSION

The recruitment of the South West African anchovy seems to be favoured at some stage, from spawning through egg development to larval survival, by reasonably constant temperatures. Conversely, it is adversely influenced by large temperature variation. Speculation on the environmental conditions that cause good or bad recruitment is made difficult by the fact that the standard deviation from the 5- or 3-month seasonal average does not take into account the nature of the temperature variation. For example, years with a large zig-zag fluctuation on a 10-day basis could have a similar standard deviation to those years showing smoother but more pronounced seasonal gradients.

None of the 10-day-mean averages during the spawning seasons from 1970 to 1978 (tabulated in Table I) fall below the temperature threshold for successful egg development (± 14°C) as determined by King *et al.* (1978), although individual temperatures may have done so close inshore on a few occasions. Therefore, ignoring predation of eggs, which should be slightly less in warmer years owing to more rapid hatching, only spawning and larval survival are left to be considered as causes of variable recruitment.

The fact that the relationship between parent stock size and recruitment in the South West African anchovy is so undefined — in the period 1970-1978, it varied by a factor of more than 10 (Butterworth and Le Clus 1979) — leads one to the conclusion that the total number of eggs spawned per season is not crucial to recruitment, provided that the number of eggs spawned per unit adult biomass per season does not vary by a comparable or greater factor. If it does not, and there is no evidence of such a large order of magnitude variation (Le Clus 1979), then larval survival is the critical factor for determining recruitment levels.

O'Toole (1977) found that the majority of anchovy larvae occurred near the frontal region of mixing between the upwelled water of the Benguela Current and the warmer, more saline oceanic and Angolan water that overlies it. The more extensive and stable the overlying frontal intrusion, the more abundant the larvae seemed to have been. However,

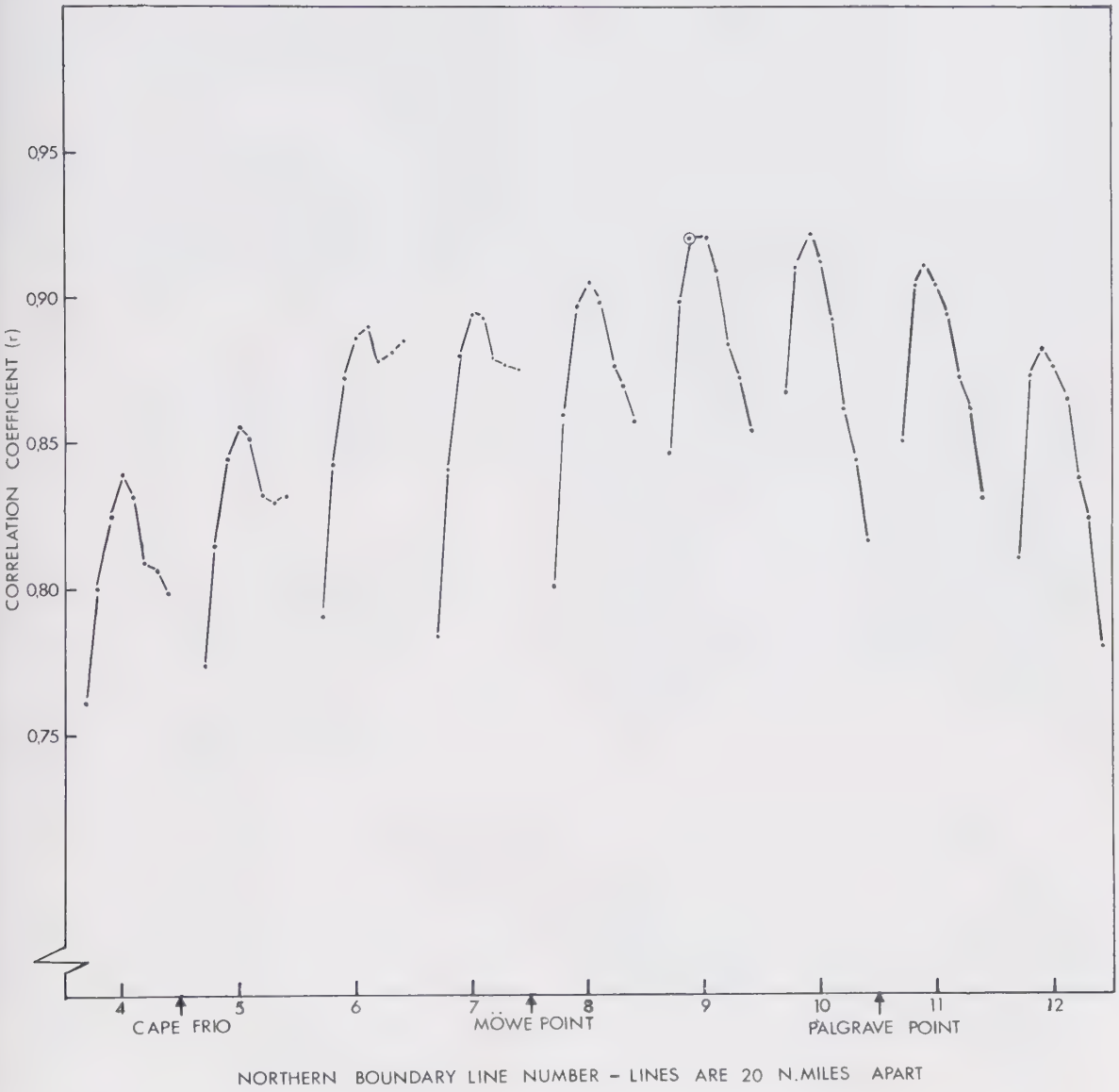

Fig. 3: Area optimization for recruitment correlation
[Each point plotted from the left to the right on each curve indicates a shifting of the southern boundary 20 nautical miles southwards from line 15 (Sierra Point) to line 22 (Hollams Bird Is.). The encircled data point indicates that the optimal correlation occurs when the area used for digitization extends from line 9 to line 17. The appropriate grid is shown in Figure 1 by means of dots.]

dominance of either upwelled water or very warm water over an area does not seem to favour larval occurrence. Thus, a small variation in the 10-day-mean spatially averaged temperatures during the spawning season generally centred around 17-19°C may reflect the maintenance of a favourable balance between upwelled water of 14-16°C and oceanic and Angolan water of 19-21°C.

Some conditions favourable for the survival of the larvae of the northern anchovy *Engraulis mordax* were discussed by Lasker (1975). The availability of food of the right type in sufficient concentration was essential for successful first feeding. Lasker (*op. cit.*) also discussed how a windstorm caused mixing in the upper layers and dispersed this food, dooming the larvae to death. If the feeding habits of *E. capensis* larvae are similar to those of *E. mordax*, this argument leads to the conclusion that little surface temperature variability reflects hydrological conditions suitable for the maintenance of a sufficient concentration of the right food for larval survival during the spawning season, whereas large variability reflects the opposite.

A test was also made to determine whether a relationship existed between temperature variability and recruitment of the same species further south in the region between Cape Point and Still Bay over its spawning season from September to January. No significant relationship was found, though this could have resulted from the implicit 10-day period of time-averaging rendering the measure of temperature variation unreliable, because of important fluctuations occurring on a smaller time scale.

It would be desirable, however, if the relationship here suggested for the South West African anchovy could be tested for other similar upwelling environments.

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LITERATURE CITED

BUTTERWORTH, D. S. and F. LE CLUS 1979 — Assessment of the anchovy (*Engraulis capensis*) in ICSEAF Divisions 1.4 and 1.5, 1968-1978. *Colln scient. Pap. int. Commn SE Atl. Fish.* **6**:171-182

KING, D. P. F. 1977 — Distribution and relative abundance of eggs of the South West African pilchard *Sardinops ocellata* and anchovy *Engraulis capensis* 1971/72. *Fish. Bull. S. Afr.* **9**:23-31.

KING, D. P. F., ROBERTSON, A. A. and P. A. SHELTON 1978 — Laboratory observations on the early development of the anchovy *Engraulis capensis* from the Cape Peninsula. *Fish. Bull. S. Afr.* **10**:37-45.

LASKER, R. 1975 — Field criteria for survival of anchovy larvae: the relation between inshore chlorophyll maximum layers and successful first feeding. *Fishery Bull., Wash.* **73**(3):453-462.

LE CLUS, F. 1979 — Fecundity and maturity of anchovy *Engraulis capensis* off South West Africa. *Fish. Bull. S. Afr.* **11**:26-38.

O'TOOLE, M. J. 1977 — Investigations into the early life history of the South West African anchovy *Engraulis capensis* Gilchrist. In *Investigations into some important fish larvae in the South East Atlantic in relation to the hydrological environment.* Ph.D. thesis, University of Cape Town; Paper 3: 38 pp.

Fish. Bull. S. Afr. 12:85—92
1979

ADAPTATIONS PERMITTING AIMED TRAWLING WITH RECTANGULAR MIDWATER TRAWLS FROM NON-FISHERY RESEARCH VESSELS

A. A. ROBERTSON

Minor modifications to a research-sized rectangular midwater trawl and to the after-deck layout of a vessel not designed for fisheries research enabled qualitative, aimed sampling for krill in the Southern Ocean to be successfully carried out as part of a general acoustic survey. Both a hull transducer and a net-sonde were used for directing the net to the target. Nets with different mesh sizes were used but their performance was not compared. Blind sampling was not attempted, but 80 per cent of the 32 hauls made proved positive.

Kleinere veranderings aan 'n navorsingsgrootte- reghoekige midwatertreil en die uitleg op die agterdek van 'n vaartuig wat nie vir visserynavorsing ontwerp is nie, het dit moontlik gemaak om kwalitatiewe, gerigte bemonstering van kril suksesvol in die Suidelike Oseaan as deel van 'n algemene akoestiese opname uit te voer. Beide 'n oordraer aan die romp en 'n netsonde is gebruik om die net op die teiken te rig. Nette van verskillende maasgroottes is aangewend, maar hul prestasies is nie vergelyk nie. Blinde bemonstering is nie aangedurf nie, maar 80 persent van die 32 trekke wat uitgevoer is, het positief geblyk te wees.

During the period February to April 1978, the Sea Fisheries Branch undertook a ten-week survey in the area of the Bransfield Strait and the Scotia Sea in order to test the suitability of various aerial and acoustic techniques for estimating the population size of Antarctic krill *Euphausia superba* Dana.

The acoustic detection of krill was primarily to be made by means of a calibrated Simrad 120-kHz echo-sounder system with either hull-mounted or towed transducers, the latter being suspended from surface float vehicles. A 100-kHz side-scan sonar was also to be deployed.

An integral part of the survey strategy was rapid identification of back-scatterers, which formed the acoustic targets on which quantitative measurements were being made and recorded with a digital data-logger. Experience gained in surveys off South West Africa had resulted in the development of a successful method of aimed trawling using a standard 8-m² Rectangular Midwater Trawl (RMT), as described by Clarke (1969), and it was decided to use this net for target identification.

The only vessel available for the survey was S.A.S. *Protea*, a Hecla-class hydrographic survey vessel of the South African Navy.

ARRANGEMENT OF GEAR

Although the vessel was suitable in many respects, towing operations presented the following problems:

(i) Apart from a sweep winch, no built-in equipment was available to facilitate towing small trawls or large plankton nets.

(ii) The after working deck was almost completely covered by the helicopter deck, leaving very little room for shooting or retrieving nets.

(iii) Any gantry or gallows arrangement could not extend higher than the helicopter deck (approximately 2,5 m) when in the stowed position.

(iv) Height above sea surface posed problems of launching and retrieving delicate towed vehicles e.g. transducers, floats and side-scan sonar towfish.

To overcome these problems, a flat-topped gantry was fitted to the after deck (Fig. 1). Constructed of 150 mm × 90 mm × 90 mm steel channel bar the unit was bolted to hinged bed plates on the deck. Three blocks were suspended from the cross bar of the gantry for the various warps, i.e. towing, net-sonde and side-scan sonar. Blocks for handling the net were suspended from brackets welded to each of the outer sides of the gantry legs. Brackets for raising and lowering the entire assembly (by means of the warping drums on the ship's sweep winch) were also fitted to the forward side of the gantry legs. When fishing, the top of the gantry protruded just beyond the stern rail and was held in a raised position by tie bars to the helicopter deck so as to permit the rig to clear the stern rail. The assembly was lowered for deployment of the side-scan sonar or when using the helicopter.

NETS

The nets used were basically standard RMT

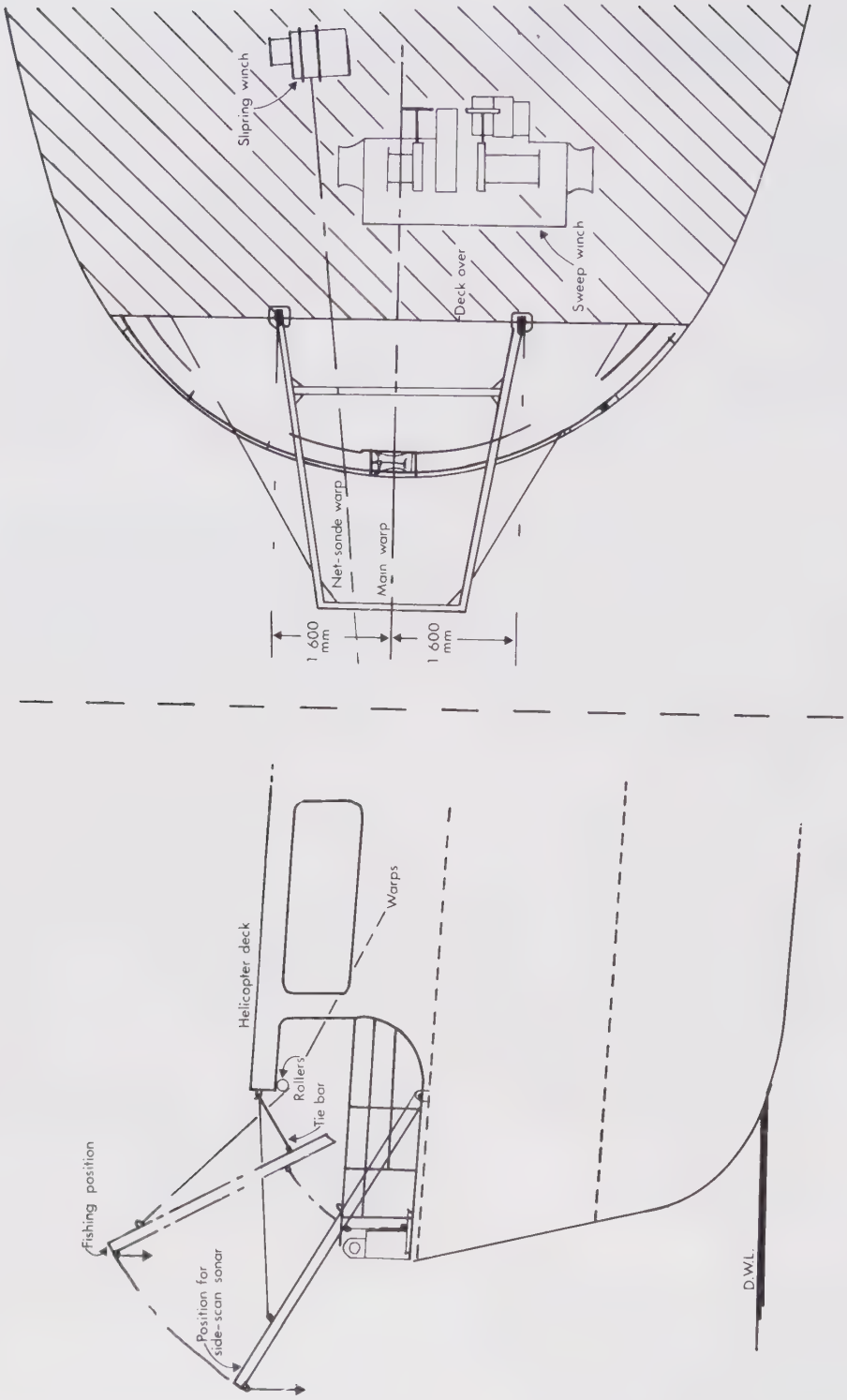

Fig. 1: Working arrangement – after deck

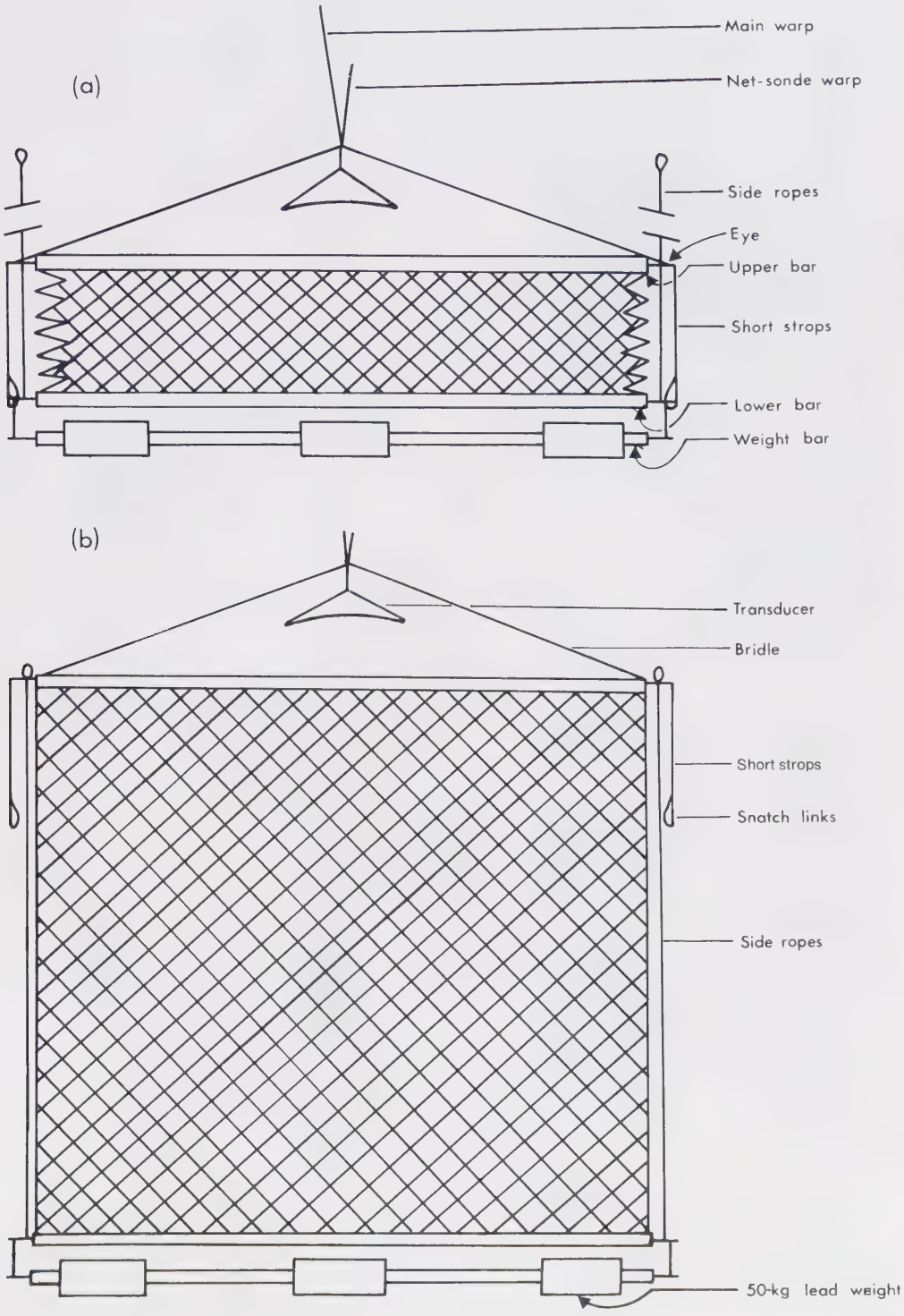

Fig. 2: Net in triced (a) and open (b) arrangement (not to scale)

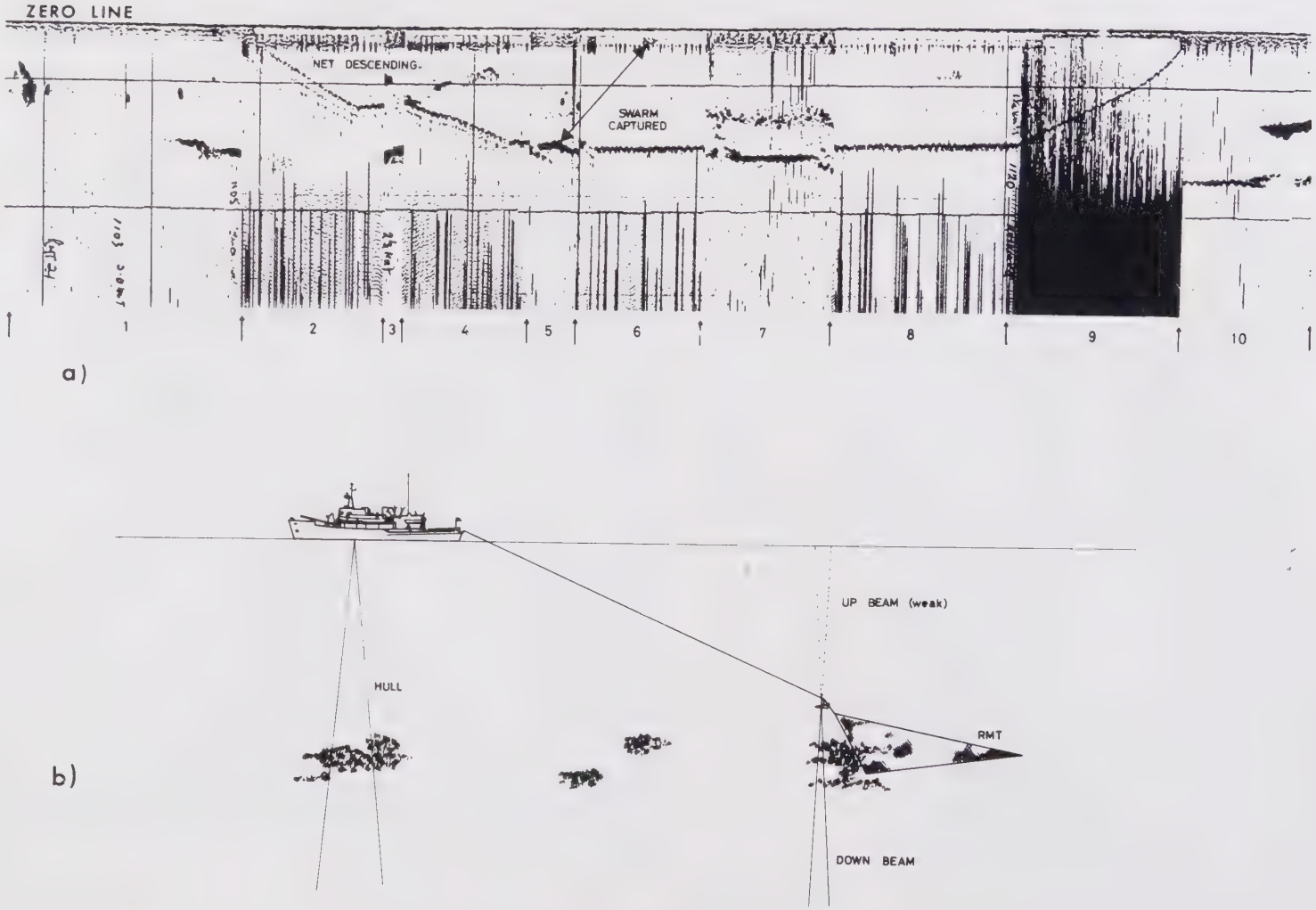

Fig. 3: Target identification with RMT and net-sonde: a) echo-trace; b) schematic

units without the opening and closing mechanism or the acoustic monitoring system. As the net had to be manhandled over the stern rail, the mass of the weights was reduced from the standard 182 kg to 100 kg. Two experimental nets were constructed with the aim of attempting to reduce frontal drag and minimize consequent reduction in effective mouth area. The one net (RMT-2) had two mesh sizes, the first 1,5 m being 30-mm (stretched) nylon mesh and the remainder, 10 mm. The other net (RMT-4) had four different mesh sizes in its construction, i.e. 105, 50, 30 and 10 mm. A net with 10-mm mesh throughout was also assembled (RMT-1).

The short distance between the top of the gantry and the stern rail made it necessary by some means to reduce the height of the net during shooting and retrieval. To this end, a method of tricing the net was devised. Two steel wire rope strops 70 cm long were shackled, one to either end of the upper spreader-bar. They could be clipped into the lower spreader-bar by means of snatch links (Fig. 2). This method reduced the height of the net, including the weight bar, to less than 100 cm. The overall height of the assembly was reduced to 150 cm by shortening the bridles to 170 cm. The net was released to its full dimension by unclipping the lower bar once the rig had been suspended over the side. This was accomplished with a polypropylene side-rope 50 mm in circumference shackled to each end of the lower bar and threaded through eyes on the upper bar. Large thimbles were spliced into the side-ropes to prevent their slipping back through the eyes during fishing operations.

NET-SONDE

The net-sonde was a 120-kHz transducer mounted in a Braincon V-fin depressor suspended from the net bridle. A multicore strain cable taken up on a portable slip-ring winch connected the net-sonde to the recorder in the laboratory. The 120-kHz Simrad echo-sounder system was used as the transceiver and recorder and could be switched from hull transducer to net transducer during operation. The purpose of the hull transducer was to initially locate targets and to monitor their presence during fishing operations.

Figure 3 gives the arrangement of the transducers during fishing (Fig. 3b) and an example of an echo-trace obtained at a selected station. The descending and ascending lines (Fig. 3a) are weak back-echoes from the surface to the net-sonde and thus indicate the actual depth of the net. The main downward beam from the net transducer detects the targets beneath the net. Distance from the zero line gives the depth of the target below the net transducer. The echo-trace is somewhat confusing, and Table I has been included to explain its various features. The full depth of the scale of the echo-trace (zero line to full deflection) is 125 m.

Table I: Description of echo-trace shown in Figure 3

Section of trace	Transducer	Explanation
1	Hull	Two strong targets — lower appears to be a layer
2	Net	Net being lowered
3	Hull	Two targets — lower layer still present
4	Net	Net being lowered to fishing depth
5	Hull	Check on continued presence of layer
6	Net	Swarm being captured
7	Hull	Check on continued presence of layer
8	Net	No targets — possibly above or too close to transducer
9	Net	Net being retrieved
10	Hull	Lower layer still present

FISHING OPERATIONS

To shoot the gear, the net was triced with the short strops and lifted with the main trawl warp until the bridle wires were hard up against the towing block. In this position, the weight bar was just below the level of the stern rail and could be easily manhandled overboard. With the rig suspended, leach lines were clipped to the eyes in the now slack side ropes and the slack warped inboard through blocks hanging on the outer sides of the gantry. Once the full weight of the lower bars was taken up, the short strops were unclipped and the net slowly opened to its full dimensions. The full rig was then lowered and fishing operations commenced. The reverse procedure was used for retrieval.

Time taken for shooting and retrieving was remarkably short under the circumstances. To get the net into the water took 3-5 minutes, depending on weather and sea conditions. Time to fishing depth varied with target depth. In some cases, the net was lowered to an intermediate depth to await

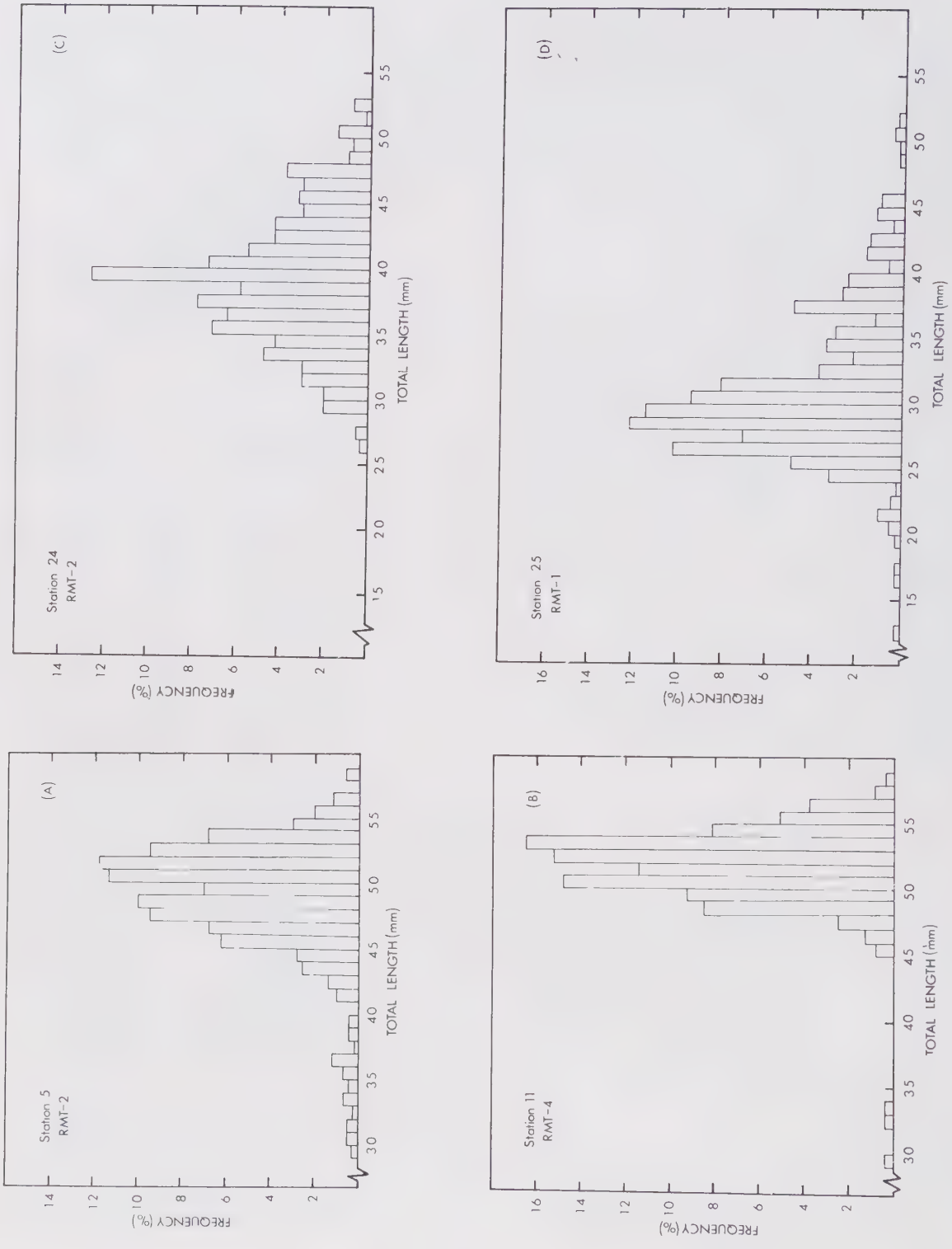

Fig. 4: Size composition of catches

deeper targets and thus reduce lowering time. The distance between the hull transducer and the net transducer, which varied with fishing depth, was generally sufficient to permit raising or lowering the net to capture a specific target. Good communication between the acoustics laboratory, the working deck and the bridge ensured that changes in fishing strategy could be implemented with the minimum of delay.

Because wire load was an unknown factor, the towing load was taken by the warp from the sweep winch as a safety measure. The strain cable for the net-sonde was paid in and out along with the main warp. Generally, little difficulty was experienced with simultaneous winching as long as both warps were kept under tension. This required the slip-ring winch to be constantly attended to avoid entanglement. On two occasions, both under poor weather conditions, the warps did, in fact, become entangled.

With RMT-2, the 100-kg weight could only maintain a mouth angle of 45° from the vertical if the ship's speed did not exceed 2 knots. In order to enable the ship's speed to be increased to 2½ knots, an extra 50 kg of lead was added. Most tows were made at this speed. RMT-4 was not used often because first indications were that most of the organisms escaped through the large frontal meshes. RMT-1 was damaged during rigging, with the result that the netting hung poorly. It was therefore only used on two occasions. Most of the hauls were made with RMT-2.

DISCUSSION

The gantry proved to be highly effective, although hydraulic luffing would have been preferable in order to eliminate manhandling the gear. It would also have drastically reduced the number of men required on each watch.

The two-winch method, although workable, should be avoided. The slip-ring winch used on the *Protea* was designed for use with Bongo nets and thus lacked power. A unit capable of handling loads of approximately 2 000 kg would probably suffice for sampling in the upper few hundred metres.

The RMT net with its net-sonde proved to be a successful krill sampler. Of the 32 hauls made, 80 per cent were positive, the largest catch being 14 kg. The success was due largely to an ability to aim the net at specific targets. Krill catches were generally homogeneous with only two stations yielding a mixture of krill and large salps.

No blind fishing was carried out and also, once it was thought that the swarm had been captured, the tow was terminated. Length of tow varied from 11 to 55 minutes, the latter being caused by warp entanglement with resultant delay in retrieval. Most tows took less than 30 minutes.

As survey time was limited, no time could be devoted to making comparative hauls with the different nets. Evaluation of their relative performance is therefore not possible. However, as the survey was centred in two main areas, namely Smith Island and the eastern approach to the Gerlache Strait, rough comparisons of the results from each of these areas may be useful. Krill catches with the effectively larger-meshed RMT-4 were generally smaller than those made with RMT-2, with a bias towards larger animals (Figs. 4A and 4B). Both of these hauls were made in the Smith Island area. In the Gerlache Strait, where smaller krill predominated, catches with RMT-1 indicated better retention of smaller animals than did those with RMT-2 (Figs. 4C and 4D). Fishing results from the *Protea* cruise were encouraging and indicate that aimed trawling techniques with RMT nets should be developed further.

Occasional target identification hauls will have to be made during acoustic surveys and should be accomplished as quickly as possible with minimum difficulty. Tows need not necessarily be time consuming, provided accurate positioning of the net with the net-sonde is achieved. Nets with an opening and closing mechanism would be of assistance where targets vary in size and depth. An electro-mechanical release mechanism, powered through a multiconductor trawl warp could be developed relatively inexpensively. More important, however, is the need to experiment with smaller nets and different mesh sizes. The lightest possible materials should be used in the construction of the frame and the net. Effort should be directed towards the development of a light-weight sampler with a net-sonde that can be handled from any vessel capable of working in the Southern Ocean.

ACKNOWLEDGEMENTS

I would like to thank the officers and crew of S.A.S. *Protea* for their assistance during the cruise. A special word of thanks goes to W. O. Sam Costar for his constant enthusiasm, displayed under often trying conditions. The encouragement of Dr D. L. Cram and the contribution of Mr F. H. Schülein to

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LITERATURE CITED

CLARKE, M. R. 1969 — A new midwater trawl for sampling discrete depth horizons. *J. mar. biol. Ass. U.K.* **49**(4):945-960 + 2 Plates.

Fish. Bull. S. Afr. 12:93—119
1979

PELAGIC TUNICATA OFF THE WEST AND SOUTH-WEST COASTS OF SOUTH AFRICA, 1964-1965

B. I. LAZARUS and D. DOWLER

Pelagic tunicates taken at 95 stations on quarterly, multi-disciplinary routine cruises between January 1964 and October 1965 were extracted from the N100H, N100B and N70V plankton samples. The survey area extended from 32°S past the southern tip of Africa to 22°E and to a maximum of 180 nautical miles off shore. Identification was to species level where possible and 26 appendicularians and 23 thaliaceans were found. The seven commonest species were *Oikopleura longicauda, O. dioica, Fritillaria formica, F. pellucida, Thalia democratica, Salpa fusiformis* and *Doliolum denticulatum*. Their distribution patterns were related to prevailing oceanographic conditions and movements of water masses. *Thalia democratica* and *Doliolum denticulatum* proved to be valuable indicators of warm Agulhas water, the 15°C isotherm apparently acting as an ecological barrier. *Oikopleura dioica* occurred predominantly close inshore in upwelled waters or off shore in waters with well defined thermoclines, presumably below the thermocline.

Pelagiese tunikate wat by 95 stasies op kwartaallikse, multidissiplinêre roetinevaarte tussen Januarie 1964 en Oktober 1965 versamel is, is uit die N100H, N100B en N70V planktonmonsters verwyder. Die opnamegebied het vanaf 32°S verby die suidpunt van Afrika tot by 22°O en tot 'n maksimum van 180 seemyl seewaarts gestrek. Identifikasie het waar moontlik tot op spesievlak geskied en 26 appendikulariërs en 23 taliasiërs is aangetref. Die sewe volopste spesies was *Oikopleura longicauda, O. dioica, Fritillaria formica, F. pellucida, Thalia democratica, Salpa fusiformis* en *Doliolum denticulatum*. Hul verspreidingspatrone is in verband met heersende oseanografiese toestande en die bewegings van watermassas gebring. *Thalia democratica* en *Doliolum denticulatum* het geblyk waardevolle indikatore van warm Agulhaswater te wees en die 15°C isoterm tree skynbaar as 'n ekologiese barriere op. *Oikopleura dioica* het hoofsaaklik naby die kus in opgewelde water of aflandig in water met goedafgebakende termoklines voorgekom, vermoedelik benede die termokline.

A survey of salps and doliolids off the coast of South Africa was made by van Zyl (1960) and this study represents a follow-up to his work. The present study was initiated by one author (D.D.), who completed all the extractions and identifications. A brief summary of her data was incorporated by De Decker (1973) in his account of the Agulhas Bank plankton. The present report is a continuation in greater detail of some of the numerically more important species which could possibly be used as indicator species of different water masses.

THE RESEARCH AREA

The routine research area consisted of 81 stations worked every month plus an additional 14 stations worked quarterly (Fig. 1). Sampling of these latter stations, along the so-called long lines, was carried out in January, April, July and October each year. Only the data collected on the quarterly long-line cruises in 1964 and 1965 are used for this report.

For reference purposes, all stations were numbered in two parts — the first, a two-digit number, represents the line and the second, the station on that line. Station 1 was always the inshore one of a line.

MATERIALS AND METHODS

Plankton nets used were of the standard "Discovery" type fully described together with mode of operation by Kemp and Hardy (1929).

The N100 nets were operated at each station (weather permitting) in order to sample the thaliaceans. A horizontal haul with the N100H net towed aft was made in the surface layer (0-5 m) for a period of 10 minutes at a ship's speed of 2 knots. The N100B nets were towed obliquely from a maximum depth of 150 m to the surface or from 20 m above the bottom if the station depth was less than 170 m. A cable angle of 60° with the vertical was maintained throughout the operation. As soon as the net reached 150 m (or the maximum depth allowed) it was hauled in at a rate of about 20 m per minute resulting in a 14-16 minute tow for a 150-m haul. N70V closing nets were operated at the following depths on the long-line stations with the aim of sampling the appendicularian population: 1 000-500 m, 500-250 m, 250-100 m, 100-50 m and 50-0 m. On stations 1-5, the N70V net was operated from a depth of 100 m to the surface or from 10 m above the bottom when the station was too shallow.

On board, the samples were preserved in 5-percent neutralized formalin. Back at the laboratories,

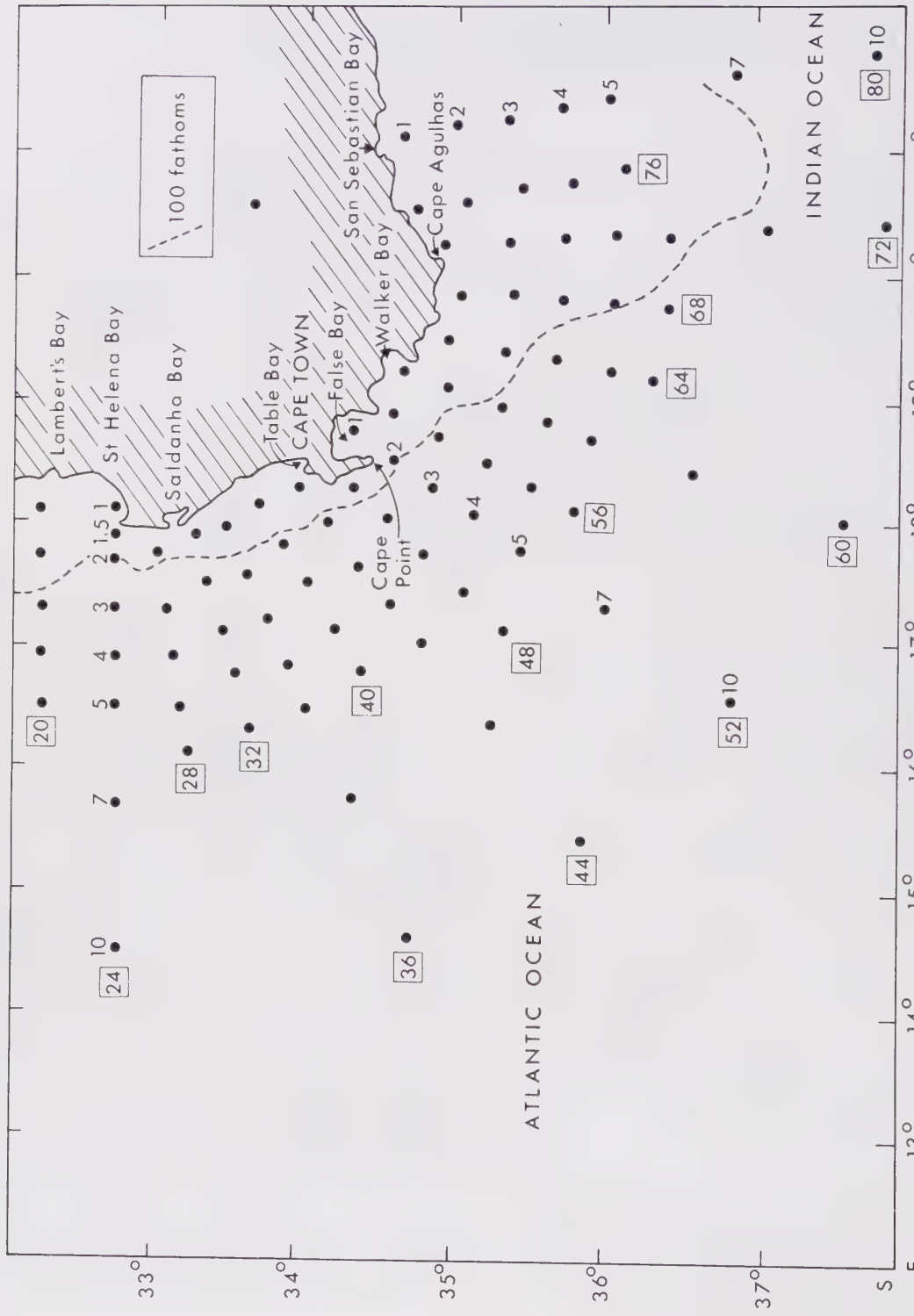

Fig. 1: Routine survey area

Table I: Appendicularia; total numbers, 1964 — 1965 (N70V nets)

Species	Number of specimens								
	January 1964 (78)*	April 1964 (73)*	July 1964 (77)*	October 1964 (73)*	January 1965 (53)*	April 1965 (53)*	July 1965 (75)*	October 1965 (69)*	Total (551)*
Oikopleura intermedia	51	122	57	0	0	0	0	0	230
Oikopleura fusiformis	2 486	4 309	1 875	1 946	434	583	4 871	10 455	26 909
Oikopleura longicauda	11 008	8 520	2 482	9 047	2 830	2 928	1 742	1 654	40 211
Oikopleura cophocerca	16	80	410	195	5	8	8 770	3 259	12 743
Oikopleura rufescens	1 210	6 370	1 479	267	64	1 312	347	620	11 669
Oikopleura dioica	3 407	1 711	8 820	925	1 340	876	352	2 664	21 095
Oikopleura parva	6	43	58	0	0	0	13	0	120
Oikopleura cornutogastra	24	517	5	0	0	419	0	0	965
Oikopleura albicans	95	202	3 752	43	1	12	134	85	4 324
Megalocercus huxleyi	36	130	4	26	0	150	0	0	346
Stegosoma magnum	100	155	32	9	2	537	9	1	842
Althoffia tumida	0	0	0	0	0	0	0	2	2
Tectillaria fertilis	25	286	0	0	0	45	14	63	433
Fritillaria formica	4 510	132	50	4	1 009	20	18	0	5 743
Fritillaria borealis	131	491	1 271	17	0	536	1 093	53	3 592
Fritillaria pellucida	158	1 363	123	713	1 837	77	1 640	2 090	8 001
Fritillaria megachile	16	0	0	0	0	0	6	2	24
Fritillaria haplostoma	16	141	0	37	3	315	16	0	528
Fritillaria fraudax	0	0	2	0	0	0	0	0	2
Fritillaria bicornis	32	0	0	0	0	0	0	0	32
Fritillaria taeniogona	0	0	0	0	0	0	0	3	3
Fritillaria sp.	8	0	0	2	0	8	16	8	42
Folia sp.	0	0	0	0	0	0	2	0	2
Oikopleura sp.	0	0	0	1	0	5	4	1	11
Kowalevskaia oceanica?	0	3	0	0	0	0	0	0	3

*Number of stations occupied

Table II: Thaliacea; presence and absence, 1964 and 1965 (N100H and N100B nets)

Species	1964				1965				Number of months found (%)
	J	A	J	O	J	A	J	O	
Thalia democratica	X	X	X	X	X	X	X	X	100
Thalia longicauda	X	X	—	X	X	X	—	X	75
Salpa fusiformis	X	—	X	X	X	X	X	X	87,5
Salpa maxima	—	X	—	—	—	—	—	X	25
Salpa cylindrica	—	—	—	—	X	—	—	X	25
Ihlea magalhanica	—	—	—	X	—	—	X	X	37,5
Iasis zonaria	—	—	—	—	—	—	—	X	12,5
Traustedtia multitentaculata	—	—	—	—	—	—	—	X	12,5
Pegea confoederata	X	X	—	X	X	X	X	X	87,5
Cyclosalpa pinnata	X	X	—	X	X	X	X	X	87,5
Doliolum denticulatum	X	X	X	X	X	X	X	X	100
Doliolum nationalis	X	X	X	X	—	—	X	X	75
Doliolum denticulatum var. *ehrenbergii*	—	—	—	—	X	—	—	—	12,5
Doliolum mirabilis	—	—	—	—	—	X	—	—	12,5
Dolioletta gegenbauri	—	X	—	X	X	X	—	X	62,5
Dolioletta tritonis	X	—	—	—	—	—	—	X	25
Pyrosoma sp.	X	X	—	—	—	—	—	X	37,5
Total number of species	9	9	4	9	9	8	7	15	

the samples were measured for settled volume, split into aliquots if too bulky and finally transferred to 6-inch by 1-inch specimen tubes.

Temperatures were determined and water samples for salinity determination taken by means of Nansen-Pettersson bottles (up to 100 m deep) or Munro-Ekman reversing bottles where deeper.

RESULTS

The total numbers of appendicularians taken at all stations visited each month are listed in Table I. Not all 95 stations were sampled each quarter owing to inclement weather and other factors. The figures in parenthesis represent the number of stations at which the nets were hauled. Table II summarizes the occurrence of thaliaceans on a basis of presence or absence during a particular month over the entire area. Individuals were not counted as were the appendicularians. The appendicularian distribution charts (Figs. 2-9) reflect the numbers caught at each station whereas the thaliacean charts (Figs. 10-15) only reflect occurrence. Stations not visited are crossed out on the distribution charts.

Seven species that occurred most commonly were selected and related to conditions prevailing at the time of sampling. This was done in an effort at explaining temperature preferences and the possible movement of water masses off the coast of South Africa. The species selected were:

Oikopleura longicauda Vogt, 1854
Oikopleura dioica Fol, 1872
Fritillaria formica Fol, 1872
Fritillaria pellucida Busch, 1851
Thalia democratica Forskal, 1775
Salpa fusiformis Cuvier, 1804
Doliolum denticulatum Quoy & Gaimard, 1835

Oikopleura longicauda

This species proved to be the most abundant of the appendicularians but was less common in 1965 than in 1964 (Table I). It showed a marked preference for the Agulhas Bank area and for Agulhas water generally. Consequently, lesser numbers were captured off the West Coast.

During January 1964, it was most common over the Agulhas Bank (Fig. 2a) in a belt approximately 40 miles off shore. Close inshore on the West

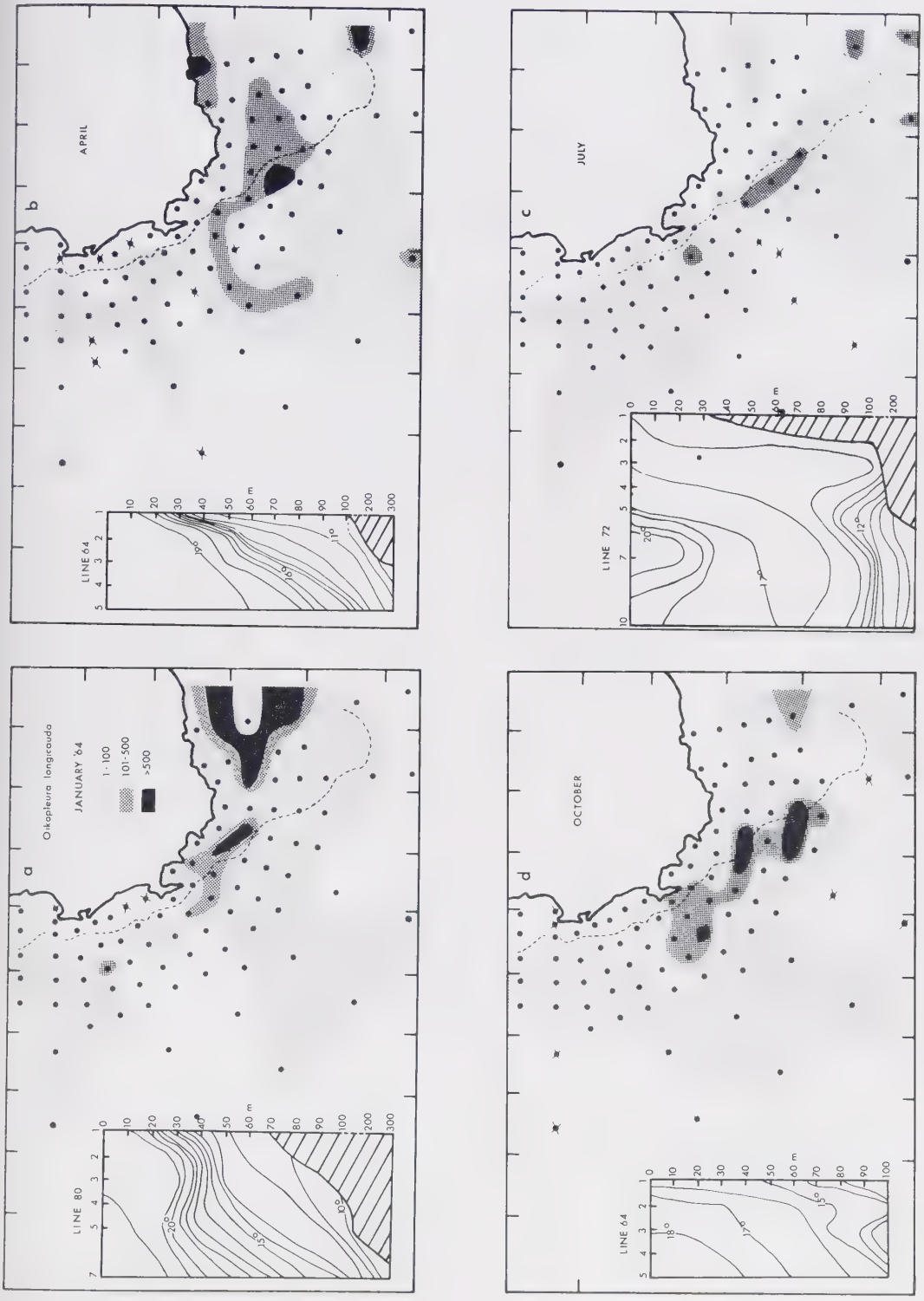

Fig. 2: Distribution of *Oikopleura longicauda* in 1964 and hydrographical parameters in selected localities

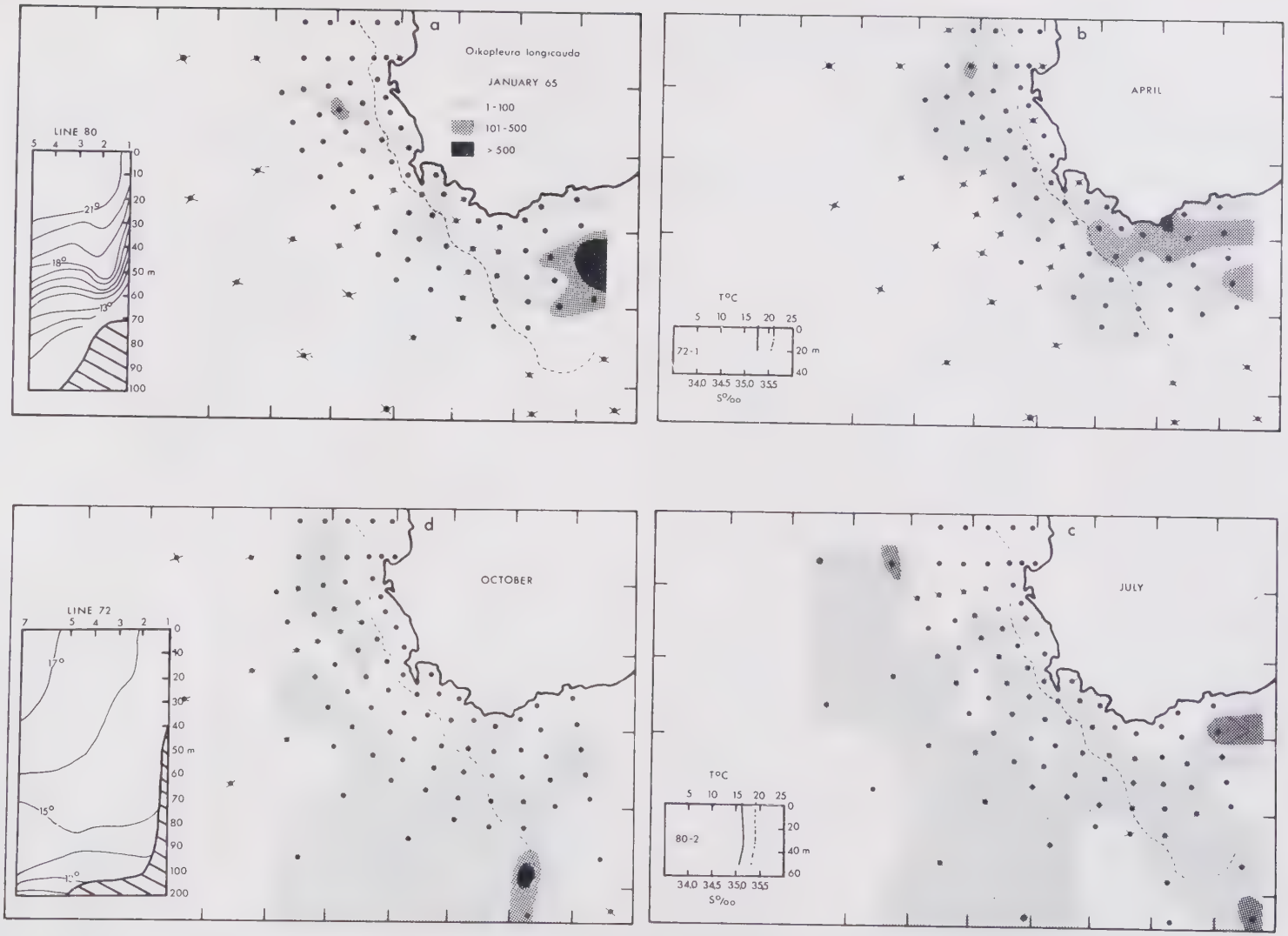

Fig. 3: Distribution of *Oikopleura longicauda* in 1965 and hydrographical parameters in selected localities

Coast, where cooler conditions were encountered, it was scarce or entirely absent. Surface temperatures in the area of maximal abundance were between 19 and 22,18° C.

The majority of the specimens were captured on line 80 between the surface and 50 m. A temperature-depth profile for line 80 (inset, Fig. 2a) shows that the species was most abundant at temperatures of 15-22°C. Fenaux (1963) regarded this as the most common species in warm oceanic waters, whilst Barnard (1958) noticed a distinct correlation between abundance of *O. longicauda* and temperature, although he considered the species to be a pelagic rather than a coastal type. Furnestin (1957), working off the coast of Morocco, found that 73-78 per cent of her specimens were taken in soundings of over 100 m but still in waters of about 15°C.

Preference for warmer waters was most vividly reflected in the distribution pattern for April 1964, when the species attained numerically maximal abundance. This pattern is illustrated in Figure 2b. The influence of the Agulhas water is most evident in the form of a tongue of warm water (19,5-22°C surface temperature) sweeping over and around the Agulhas Bank and penetrating slightly northwards (to station 40-3 where the surface temperature recorded was 19,40°C). This pattern represents a late summer penetration of warmer water into the area of investigation.

Thermoclines were generally well developed, occurring between 20 and 50 m. Temperature-depth profiles over line 64, where maximal numbers were captured, indicate that the species occurred most commonly in waters of 17-20°C in the 50-0 m hauls.

By July 1964, the pattern of distribution had changed slightly, although vestiges of the April pattern were still evident (Fig. 2c). *O. longicauda* was still confined largely to the Agulhas Bank area and south-eastwards, but was slightly more plentiful off the Cape Peninsula, where temperatures of the order of 16-18°C prevailed. At station 80-10, where most of the specimens were taken between the surface and 50 m (416 out of 440 specimens), the surface temperature recording was 21,81°C, whereas the temperature at 50 m was 21,77°C and at 200 m, 16,04°C, representing well mixed waters. Specimens were captured at depths between 250 m and 100 m. The temperature at 272 m was 14,23°C.

Inshore upwelling east of line 52 precluded *O. longicauda* from populating the neritic areas, but further off shore the species proved plentiful. Temperature-depth profiles along line 72 (Fig. 2c, inset) are typical of the conditions during July 1964 and show that *O. longicauda* was most abundant in a warm-water tongue of 16-20°C situated off shore.

A more confined distribution was noted in October 1964 (Fig. 2d), the main body being over the Agulhas Bank but more widely spread in the waters off the Cape Peninsula than in the previous surveys. Temperature recordings at the surface were slightly lower than on previous occasions, being of the order of 16-18°C. The species was almost entirely absent close inshore where cooler (10-14°C) conditions prevailed.

The water proved to be well mixed, and similar numbers of *O. longicauda* were captured in depths up to 100 m at stations where the temperature varied between 14°C at 100 m and 18°C at the surface.

Three areas of abundance were found in January 1965 (Fig. 3a), with maximal numbers in the extreme eastern section where the prevailing temperature was approximately 21°C at the surface (Fig. 17a). On lines 52 and 56, the surface temperature was 19°C and at station 32-3, where 288 specimens were captured, the surface temperature was 20,08°C.

During January 1965, as in October 1964, *O. longicauda* was captured in warm, well mixed waters varying between 18 and 21°C between the surface and 50 m (inset, Fig. 3a).

Inshore upwelling off the West Coast was possibly responsible for the distribution pattern of April 1965 (Fig. 3b). The surface temperature at station 72-1 was 21,04°C and 576 specimens were captured. The depth sounding at this station was 36 m and the temperature at 20 m was 20,77°C. The salinities at the surface and at 20 m were 35,26 and 35,31‰ respectively. Such warm, highly saline, well mixed waters proved typical for *O. longicauda.* Off the West Coast, however, the surface temperature inshore was approximately 14°C, with the result that *O. longicauda* was confined off shore in water of about 18°C, e.g. station 24-4 where 120 specimens were captured (18,39°C), and station 32-3 where 96 were taken in surface waters (18,47°C).

The three main areas of abundance were still evident in July 1965 (Fig. 3c), the species not being markedly abundant in any one particular area. Temperatures of 14,5-16°C were associated with lower numbers of *O. longicauda.* Once again it was almost entirely absent close inshore. The large number taken at station 80-10 were from a water column of 19,45°C at 91 m deep and 21,09°C at the surface. The 258 specimens captured at station 80-2 were also from well mixed waters varying in temperature between 15,90°C at 50 m and 15,95°C at the surface. Salinity at this station ranged from 35,34‰ at 50 m to 35,35‰ at the surface.

During October 1965, the majority of the *O. longicauda* specimens was taken over the Agulhas

Bank and far off shore on stations 7 and 10 of the long lines (Fig. 3d). The large swarm observed at station 72-7 was associated with a surface temperature of 17,89°C and a surface salinity of 35,25‰. A total of 788 of the 790 specimens taken at this station were from the 50-0 m haul. The temperature at 50 m was 16,74°C and the salinity, 35,39‰. The waters over line 72 were well mixed and varied little in temperature between stations 1 and 7 (Fig. 3d, inset).

It is clear from the data examined that *O. longicauda* is a species preferring fairly warm, well mixed waters of surface temperature 16-20°C. Most of the captured specimens were from the upper 50 m and indicated the intrusion of Agulhas water into the sampling area. According to Thompson (1948), the species is found in regions where a certain degree of mixing of colder water occurs, e.g. off Peru and southern California. Both these areas and the west coast of South Africa are known to be influenced by upwelling, and it is therefore not surprising to find that the present data are in keeping with the already known preferences of the species.

Oikopleura dioica

This species proved to be less abundant than *O. longicauda* and characterized cooler conditions associated with upwelling of subsurface water. It was most common close inshore, mainly off the West Coast and in the Walker Bay area. In 1964, it comprised 18 per cent of the total appendicularians captured but in 1965, only 10 per cent. According to Fenaux (1963), *O. dioica* is more frequently encountered in temperate than in tropical waters and is considered by various authors (Furnestin 1957, Tokioka 1960) to be rare in the open sea and abundant in the coastal zone.

The largest concentrations in January 1964 were close inshore in Walker Bay and False Bay and about 40 miles off shore between lines 36 and 20 on the West Coast (Fig. 4a). Maximum numbers were taken in waters of 14-16°C on lines 48-60 where the surface salinity ranged between 34,90 and 35,30‰. Off the West Coast, the major concentration was centred around waters of about 16°C. The 840 specimens taken at station 56-1 were from a water column of 16,69°C at the surface and 10,85°C at a depth of 75 m. Corresponding salinities were 35,14 and 34,94‰ respectively.

The inshore distribution of *O. dioica* was more marked in April 1964 (Fig. 4b) when the majority of the specimens were captured at stations 1 and 2. The high number captured in the 50-0 m haul at station 80-7 was associated with temperatures of 22,60°C at the surface and 12,98°C at 50 m. It is presumed that the specimens were captured below the thermocline. According to Thompson (1948), this species is eurythermal as well as euryhaline and is more plentiful in cooler waters, being most abundant in the coastal zone. Present findings are in agreement with this. A temperature gradient at station 28-1 of 13,84°C at the surface and 8,48°C at 150 m characterized the sample yielding 296 specimens.

In July 1964, the species attained its maximal abundance over the two-year period of investigation and was distributed in a continuous swarm originating south of the Agulhas Bank, continuing in a ribbon-like belt over the Bank and fanning out to cover almost the entire sampling area off the West Coast (Fig. 4c). The immense swarm (4 480 specimens) taken at station 60-1 was in water 15,35°C at the surface and 14,48°C at 50 m. The respective salinity values were 35,26 and 35,19‰ (Fig. 4c, inset). Offshore upwelling is known to occur south and southwest of the Agulhas Bank (De Decker 1973) and the distribution in July 1965 could have resulted therefrom.

The pattern of distribution was more or less repeated in October 1964, although the inflow from south of the Agulhas Bank appeared to have a more westerly origin (Fig. 4d). Specimens did occur over the Agulhas Bank, however, and high numbers were associated with a temperature of 15,79°C and a salinity of 35,45‰ along line 72 in well mixed water. There was little or no variation in either temperature or salinity over the 50-0 m water layer sampled. Most specimens were captured at stations 52-1 and 48-1, where the respective surface temperatures were 16,24 and 16,00°C and the temperatures at 30 m were 12,99 and 10,26°C respectively. These temperature gradients over so shallow a depth indicate the presence of cooler water at known upwelling sites at the time of the year when south-easterly winds predominate. The presence of *O. dioica* in abundance in such cold water is in keeping with its known preferences.

Similar observations were made in January 1965 (Fig. 5a), when 664 specimens were taken in a 30-0 m haul with an N70V net at station 52-1. The water temperatures in this column varied from 12,75°C at 30 m to 16,27°C at the surface (inset, Fig. 5a). At stations 40-3 and 40-2, the surface temperatures were 19,93 and 16,45°C and the temperatures at 100 m were 13,16 and 9,26°C respectively. The *O. dioica* specimens were probably captured in the lower water layers at these stations

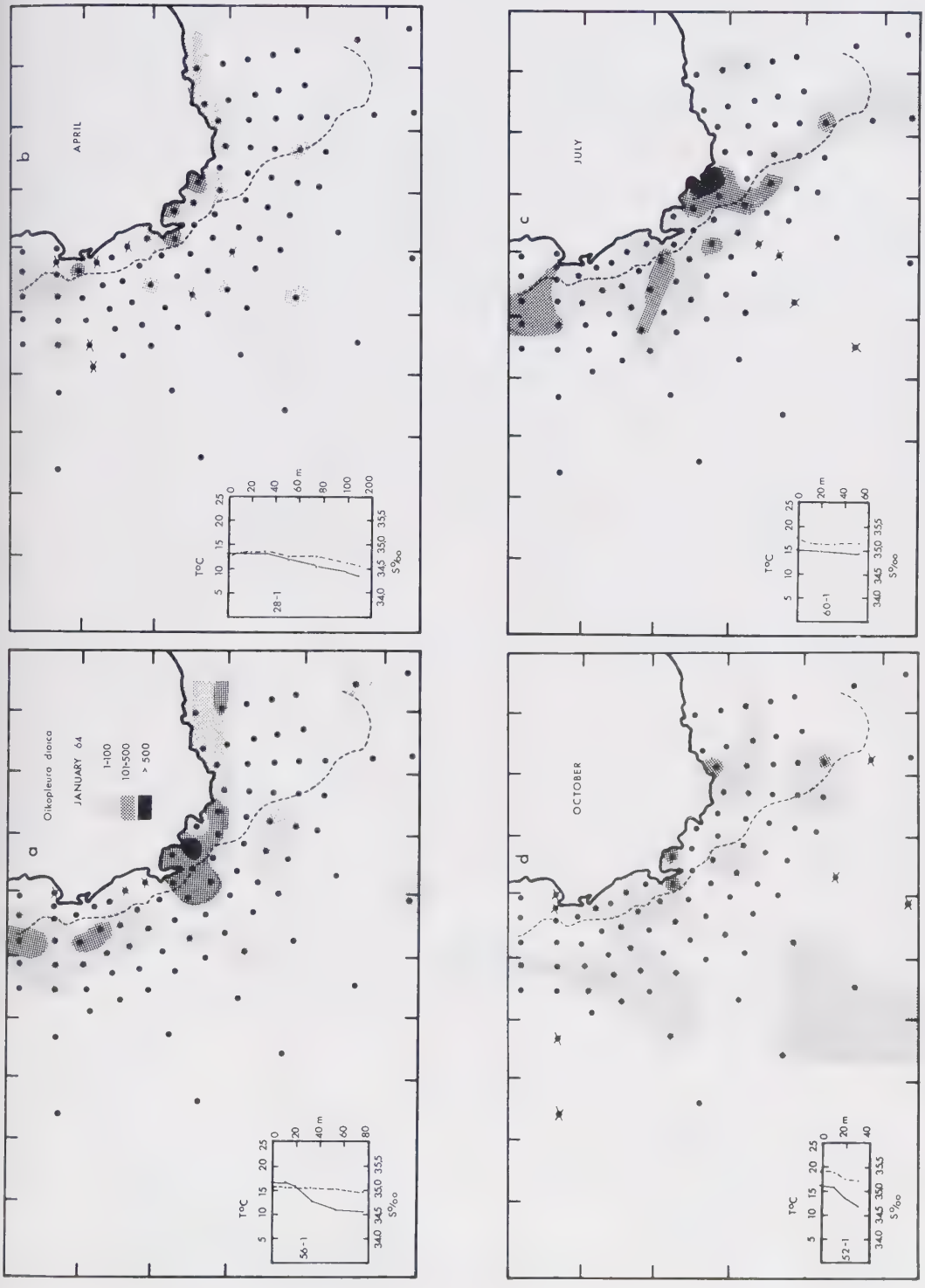

Fig. 4: Distribution of *Oikopleura dioica* in 1964 and hydrographical parameters in selected localities

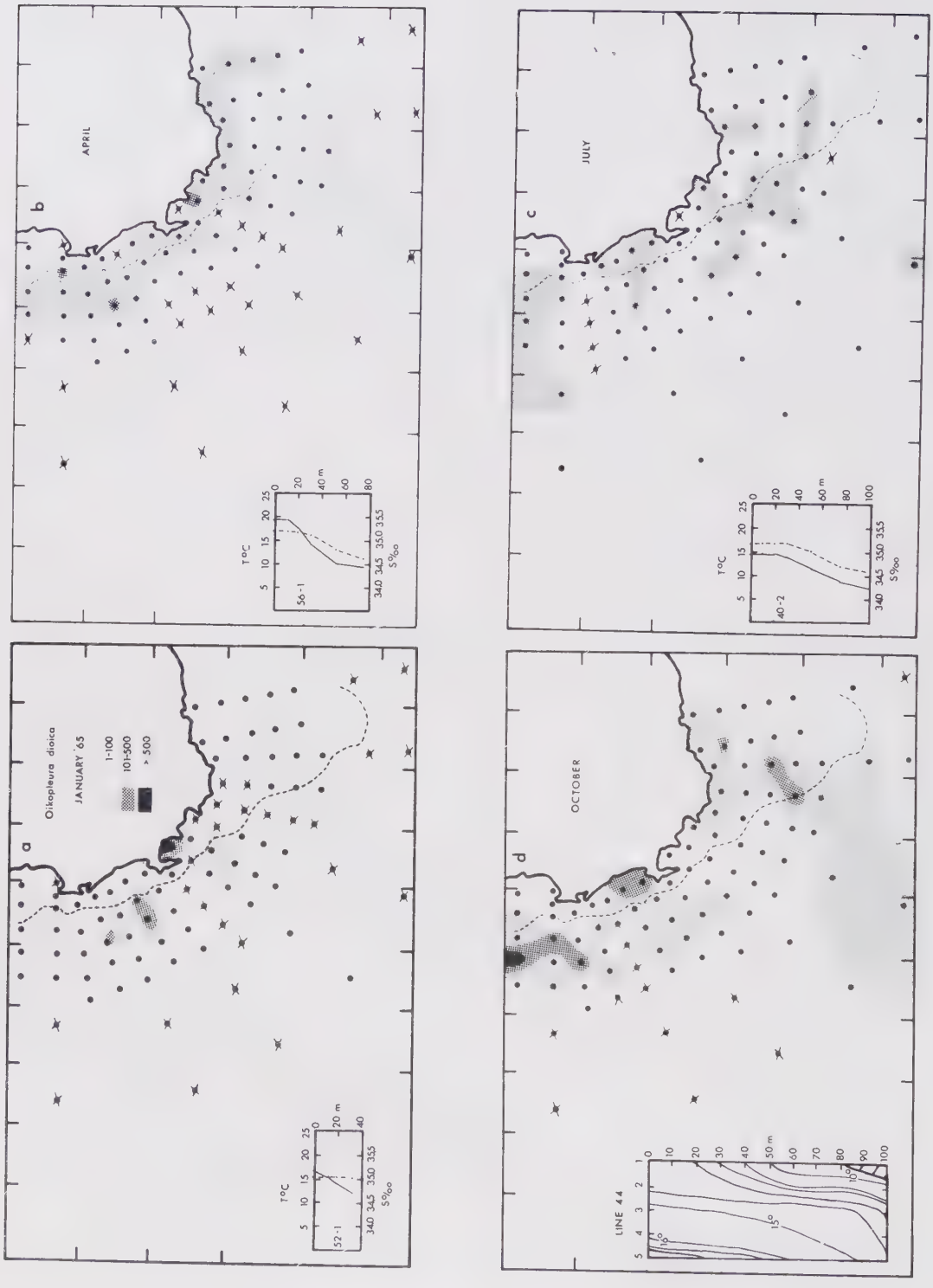

Fig. 5: Distribution of *Oikopleura dioica* in 1965 and hydrographical parameters in selected localities

and not in the warmer surface layers, the thermocline occurring at 60 m.

A more continuous distribution occurred in April 1965, but it was restricted to the inshore stations, especially over the Agulhas Bank area (Fig. 5b). Most of the specimens were taken in the Walker Bay area, e.g. station 56-1 in the 50-0 m water layer where the temperature ranged from 10,35 to 19,57°C. Salinities over the same depth range varied between 34,75 and 35,20‰.

On the winter cruise of July 1965, *O. dioica* was more scattered over the Agulhas Bank area, and off the West Coast it was confined largely inshore, except off St Helena Bay where it was encountered at station 24-7 (Fig. 5c). *O. dioica* was never plentiful during the month, the most specimens (48) having been taken at station 40-2, where the temperature and salinity ranges over the 100-0 m water column sampled were 7,81-14,22°C and 34,57-35,19‰ respectively (inset, Fig. 5c). The specimens taken in the 500-250 m haul at station 60-10 were from waters of between 4,80 and 9,11°C. The off-shore upwelling known to occur south-west and south of the Agulhas Bank (De Decker 1973) could act as a source of recruitment to species such as *O. dioica.*

This hypothesis is supported by the distribution of the species in October 1965 (Fig. 5d). A definite "tongue" of the organisms extended over the Agulhas Bank and south of the sampling area. All the specimens in abundance in the Agulhas Bank area (stations 76-2, 72-3 and 68-4) were taken from well mixed water varying little in temperature, viz. 15-16°C over the 100 m hauls. At stations 40-1 and 44-1, however, the temperatures varied between 9,60 and 14,35°C over the 50-0 m hauling distance, indicating a well defined thermocline and the presence of cooler subsurface water in which the specimens were no doubt captured (Fig. 5d, inset). At the off-shore stations on the West Coast that yielded large numbers of *O. dioica* (28-3, 24-3 and 20-4), the waters were again fairly well mixed, varying in temperature between 12 and 15°C at 28-3 and 20-4 and between 10,50 and 14,37°C at 24-3, where a total of 216 specimens were captured in the 100-0 m haul.

Judged on the occurrences of numerical maxima off the West Coast, it would appear that *O. dioica* favours the cooler subsurface waters deeper than 40 m (stations 44-1 and 40-1) and is then distributed further off shore, maintaining maximal abundance at stations 28-3, 24-3 and 20-4. Possibly *O. dioica* thrives in the cooler, upwelled inshore waters and is subsequently displaced further off shore.

A comparison of the two species of *Oikopleura* discussed indicates that *O. dioica* was far less abundant overall than *O. longicauda.* It, however, predominated in the cooler inshore areas characterized by upwelling of cold, subsurface water. Similar findings were also noted by Lazarus (1974) from inshore zooplankton samples taken between Table Bay and St Helena Bay.

Fritillaria formica

This appendicularian occurred most frequently in samples taken in January, both in 1964 and 1965 (Figs. 6 and 7). It is a eurythermal species (Thompson 1948) and was encountered in waters ranging between 9 and 21,50°C.

In January 1964 (Fig. 6a), the patches of maximal abundance centring on stations 24-5, 56-2, 72-2 and 72-3 all coincided with surface temperatures of above 20°C. At station 72-2, 1 776 specimens were extracted from a 100-0 m sample taken in temperatures varying between 21,49°C at the surface and 12,70°C at 100 m. Salinities were 35,57 and 35,28‰ respectively. It is not known if the specimens were captured above or below the thermocline which occurred at about 60 m. The entire patch over the Agulhas Bank was encountered in surface waters where the temperature was above 21°C (Fig. 16). The temperature ranges at stations 24-5, 56-2, 72-2 and 72-3 were all between 12°C at 100 m and 21°C at the surface, in keeping with the known tolerance range of *F. formica.*

The same temperature tolerance was noted in April 1964 (Fig. 6b) and July 1964 (Fig. 6c), but the four specimens captured in October 1964 at station 28-1 (Fig. 6d) were in waters registering 15,17°C at the surface and 8,61°C at 100 m. These represented the lowest temperatures both at the surface and at 100 m in which *F. formica* was captured (inset, Fig. 6d).

The large numbers captured at the eastern extremity of the area during January 1965 (Fig. 7a) were all in waters between 10°C at 100 m and 22°C at the surface (e.g. station 80-5, where 288 specimens were captured in temperatures of 21,47°C at the surface and 10,32°C at 100 m).

F. formica was only recorded twice during April 1965 (Fig. 7b), on both occasions in waters with a well defined thermocline resulting in temperatures as disparate as 21,15° C at the surface and 12,48° C at 50 m (Fig. 7b, inset station 80-1).

The two specimens taken at station 80-4 in July 1965 (Fig. 7c) were from surface water of 17,18°C (the only recording made at the station) which represented the lowest surface temperature in which the species was recorded during the particular

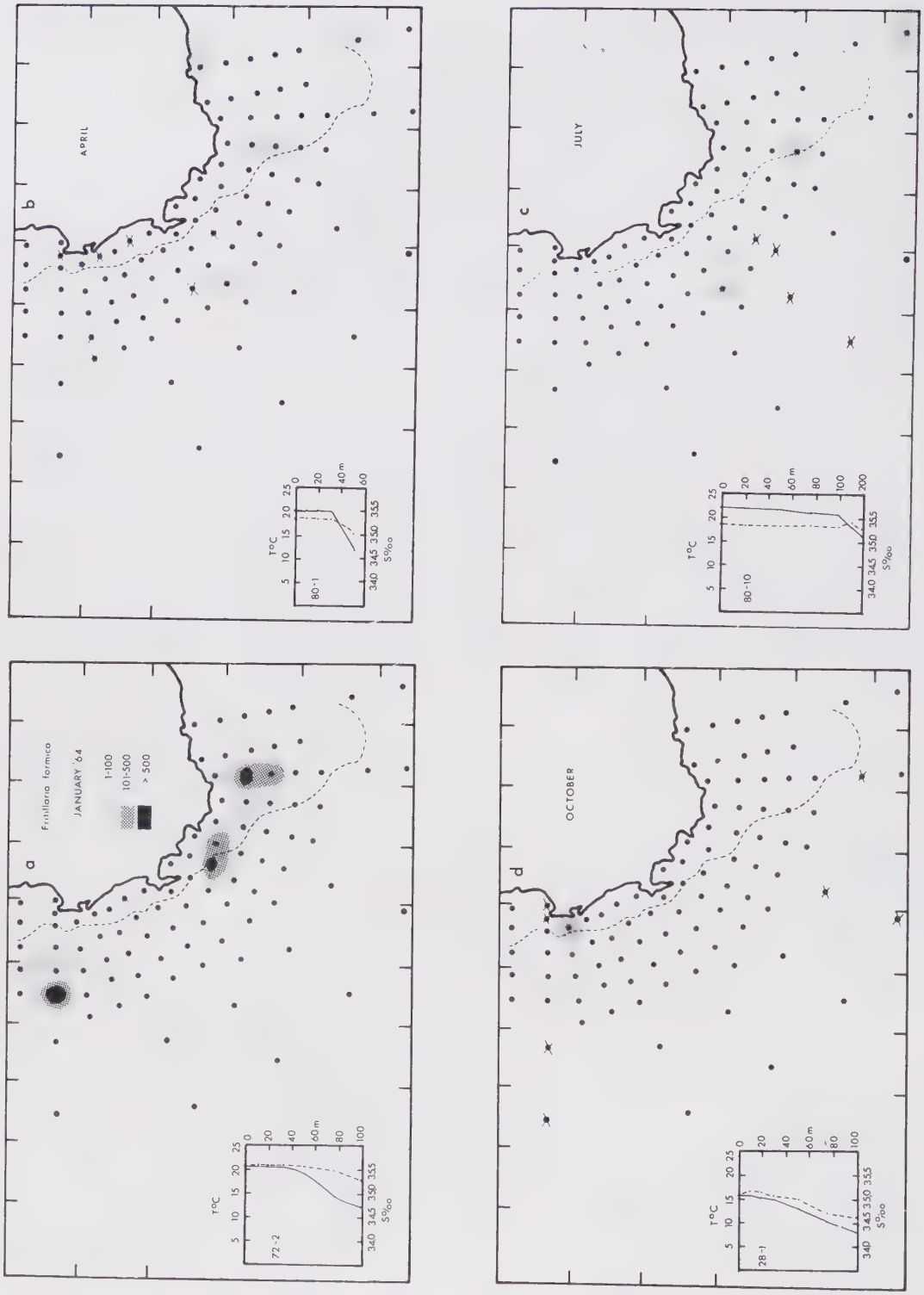

Fig. 6: Distribution of *Fritillaria formica* in 1964 and hydrographical parameters in selected localities

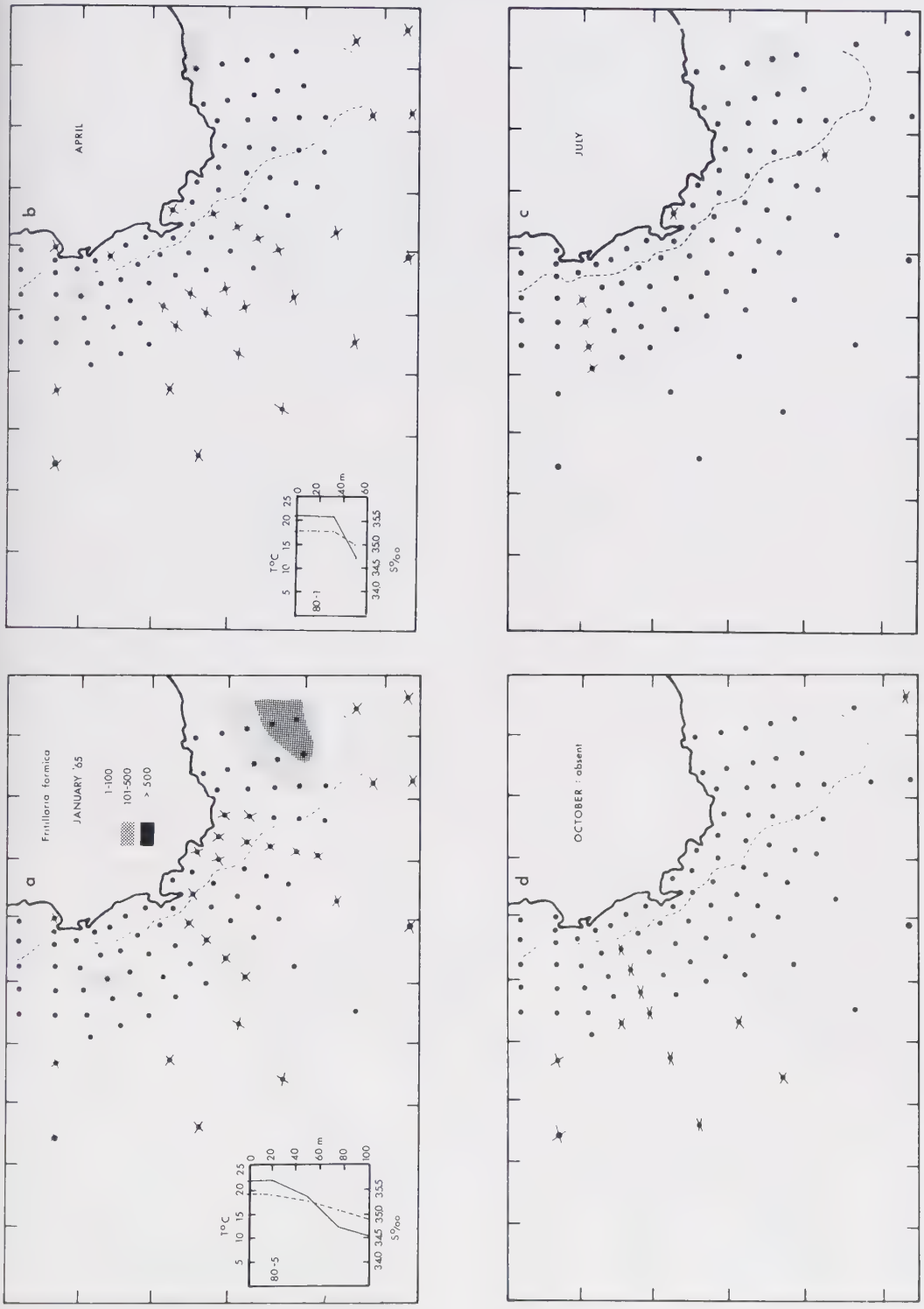

Fig. 7: Distribution of *Fritillaria formica* in 1965 and hydrographical parameters in selected localities

Fig. 8: Distribution of *Fritillaria pellucida* in 1964 and hydrographical parameters in selected localities

year. No specimens were captured in October 1965.

Fritillaria pellucida

This species proved to be consistently more abundant than *F. formica* and showed a clear north-westerly movement in distribution in the course of both years investigated. It occurred throughout the year, especially inshore. A common species, it occurs in a wide range in all the warmer oceanic regions (Thompson 1948). In the present investigation, however, it proved to be more abundant in cooler water. Although the distribution pattern was similar for both years, the numbers taken in 1965 far exceeded those of 1964, the respective percentage of the annual appendicularian total being 10 and 3 per cent.

The distribution patterns for *F. pellucida* are illustrated in Figures 8 and 9. It was taken over the Agulhas Bank during all months of 1964 but reached a minimum in July when, overall, it was more confined to the waters off the Cape Peninsula and off the West Coast. Maximal abundance was noted in waters varying between 10°C at 100 m and 17°C at the surface, e.g. station 60-1 in April 1964. The greatest numbers taken in 1965 were during July, when 992 specimens were captured at station 40-1 (Fig. 9c) in waters of 11,05°C at 150 m and only 14,56°C at the surface. This indicates a preference for cooler waters than was the case with *F. formica,* and possibly explains the greater abundance of *F. pellucida* over *F. formica* in an area where the upwelling of cooler, subsurface water is a well documented phenomenon.

Thalia democratica

Specimens occurred the whole year round although their numbers declined sharply during the winter months. In January 1964 (Fig. 10a), the species was abundant over the Agulhas Bank and in the waters off Saldanha Bay and St Helena Bay. Between lines 48 and 32, its distribution was limited largely to a belt of water approximately 60 miles off shore almost parallel to the coast. The warm water close inshore along line 24 (inset, Fig. 10a) is characterized by the presence of *T. democratica.* According to De Decker (1973), such a pattern of distribution is indicative of the presence of two water masses between which the water carrying the salp swarms is hemmed in. Both the solitary and the aggregate form were present.

By April 1964 (Fig. 10b), the organisms were concentrated mainly off shore and only a few aggregate forms were found at inshore stations on the West Coast and on lines 80 and 64. The pattern of distribution appears to be one emanating from a source to the south and south-west of the Agulhas Bank, then being swept north-westwards off the West Coast and finally impinging shoreward in tongues of warmer water of 14-19°C. Strong upwelling close inshore on line 48 (Fig. 10b, inset) probably displaced the species further off shore (stations 4 and 5), where it was found in waters of above 15°C.

The pattern for July 1964 (Fig. 10c) showed that the species was restricted almost entirely to the West Coast, with a few scattered occurrences between lines 68 and 80. All specimens were captured in waters warmer than 15°C. Temperatures inshore were less than 14°C at the surface and cooler below, and the species was absent. Along line 36 (inset, Fig. 10c), which showed typical winter conditions with well mixed oceanic water off shore and slight cooling inshore, *T. democratica* was captured at all stations except the first, where a temperature of below 15°C prevailed.

In October 1964, the species was once again widely spread although largely absent in the east (Fig. 10d). The highest concentrations were still in a belt roughly 60 miles off shore, with the solitary and the aggregate form being equally abundant.

The summer distribution in January 1965 (Fig. 11a) was almost exactly opposite to that of July 1964 (winter), the species being largely absent on the West Coast but widespread over the Agulhas Bank. The surface temperatures in the area of maximal abundance were between 19 and 21,5°C (Fig. 11a, inset).

During April 1965 (Fig. 11b), *T. democratica* was abundant over the Agulhas Bank and along the West Coast, though it was absent inshore. Between lines 40 and 20, the surface temperatures at station 1 were all between 13 and 14,5° C (inset, Fig. 11b), possibly indicating upwelled inshore water which *T. democratica* might tend to avoid. However, the inshore stations between lines 80 and 52, where surface temperatures of between 18 and 22°C were recorded, also yielded no *T. democratica,* with the exception of station 60-1. Temperatures at these inshore stations did, however, reveal sharply defined thermoclines, e.g. stations 68-1 and 64-1 where temperatures varied between 9 and 18°C over the upper 50 m. It is possible that the salps were physically excluded by the large phytoplankton concentrations observed close inshore between lines 48 and 68 (D. Horstman, Sea Fisheries Branch, personal communication).

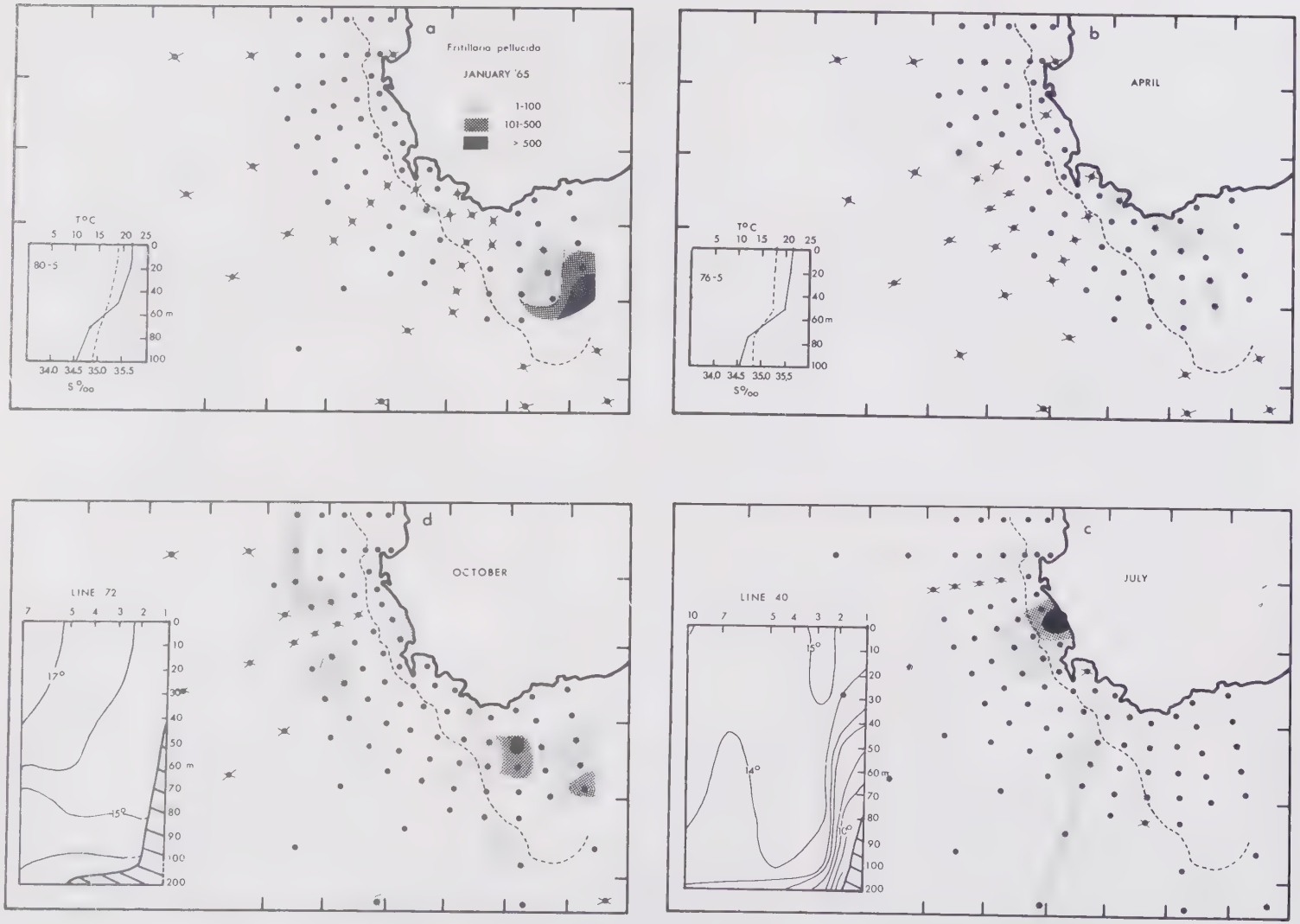

Fig. 9: Distribution of *Fritillaria pellucida* in 1965 and hydrographical parameters in selected localities

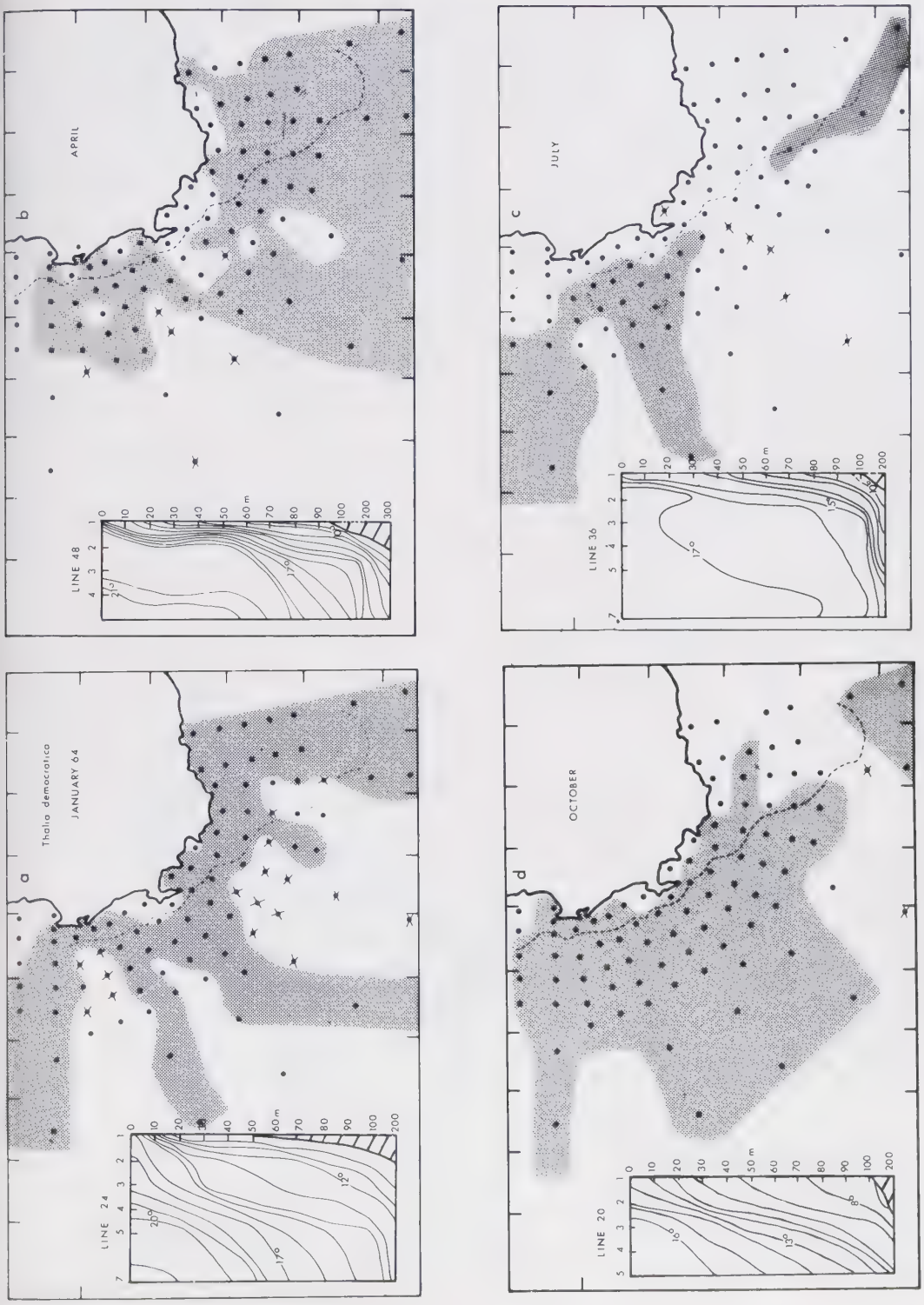

Fig. 10: Occurrence of *Thalia democratica* in 1964 and hydrographical parameters in selected localities

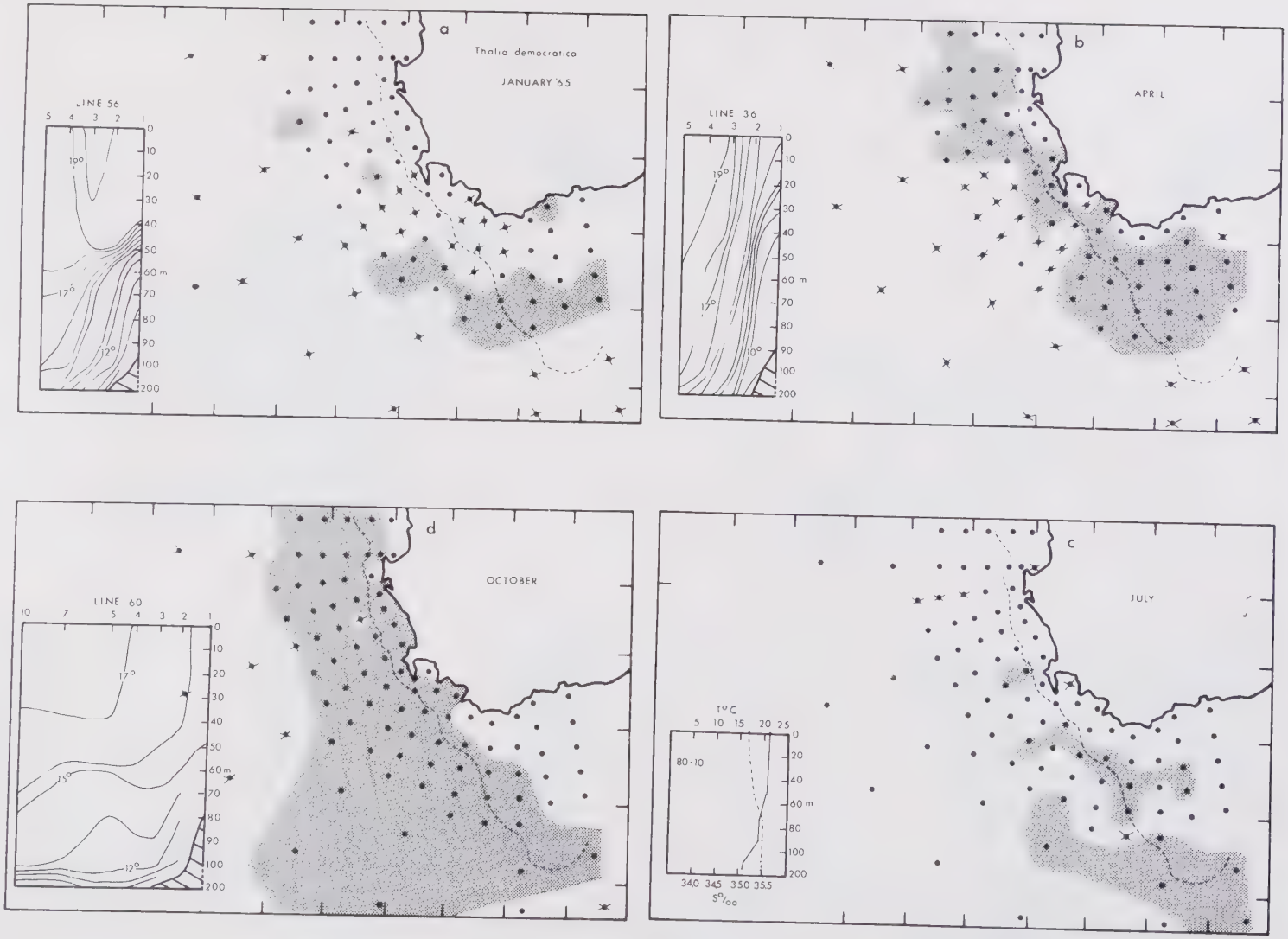

Fig. 11: Occurrence of *Thalia democratica* in 1965 and hydrographical parameters in selected localities

In contrast to July 1964, in July 1965 the species was found mainly over the southern area (Fig. 11c), although once again it was scattered and never abundant. The north-westerly winter conditions no doubt served to break up the widespread distribution noted in autumn of both years. The warm, well mixed waters at station 81-10 (inset, Fig. 11c) were associated with maximum abundance of *T. democratica* during this particular month.

By October 1965 (Fig. 11d), the species was again present on all except the most easterly stations, being widely spread over the Agulhas Bank and off the West Coast except inshore at stations 28-1, 24-1 and 20-1, where the surface temperatures were approximately 14°C. Warm, uniform conditions over the Agulhas Bank (Fig. 11d, inset line 60) again yielded large numbers of this species. It is interesting to note that at station 80-7, where the surface temperature was 17,24°C, both solitary and aggregate forms were captured, but on the other stations along this (and neighbouring lines), where surface temperatures were lower, *T. democratica* was absent. Solitary forms were more abundant during the summer months than during the rest of the year.

Salpa fusiformis

Although this species was found during seven of the eight long-line cruises undertaken during 1964 and 1965, it was nevertheless rare and occurred in notable concentration only in October each year.

During January 1964 (Fig. 12a) and July 1964 (Fig. 12c), the species was recorded only four times and in the solitary stage only once, in July. In January, the three captures were all made in waters of 19,28-21,51°C surface temperature. No specimens were captured in April 1964. In July 1964, *S. fusiformis* was taken from waters with a surface temperature of 18,26°C and a surface salinity of 35,40‰.

A fairly widespread distribution of the species was noted in October 1964 (Fig. 12d), but mainly in the area off Walker Bay and off the West Coast. The samples consisted predominantly of aggregate forms caught inshore off Walker Bay and fanning out off shore over the West Coast. Only on line 32, where the surface temperature was 15,02°C at station 32-1, did the species penetrate inshore. Thompson (1948) also noted meagre catches during the coldest season in Australian waters and an increase in abundance over the warmer months, the February-June period being the time of maximal abundance. This is not entirely in keeping with the present findings and, although the colder months yielded low numbers of *S. fusiformis,* maximal numbers were captured during October each year. De Decker (1973) pointed out that, because analogous conditions do not coincide at the same time of the year, the Australian (Thompson *op. cit.*) and South African distributions should not be compared. The species appears to favour fairly warm, well mixed water, e.g. at stations 60-5 and 56-5 the temperatures varied between 15,1°C at 100 m and 18,5°C at the surface (inset, Fig. 12d). On the West Coast, low temperatures were recorded inshore, e.g. 13,23°C at 40-1, 13,86°C at 36-1 and 10,33°C at 44-1, and no specimens were captured. The 15°C isotherm is possibly an ecological barrier to the distribution of *S. fusiformis.* Over the Agulhas Bank (lines 68-76), well defined thermoclines were evident between the surface and 100 m, e.g. 17,74 and 12,81°C at station 64-3. The presence of cool, subsurface water could preclude the presence of *S. fusiformis,* the distribution pattern of which would correspond to that of the well mixed water moving northwards from south of the Agulhas Bank into the Walker Bay area and then spreading out northwards off shore on the West Coast.

During January and April 1965 (Figs. 13a and 13b), *S. fusiformis* was again scarce, occurring at only six and four stations respectively. Solitary and aggregate forms were both observed but never in sufficient number to draw any conclusions. The distribution in January 1965 may represent remnants of the widespread distribution in October 1964. This pattern then continued through to April 1965.

By July 1965, the species was more widely spread (Fig. 13c) but still rare. Aggregate forms were more common than solitary forms, but still no discernible pattern in relation to environmental parameters could be deduced. The influx appeared to have come from the south-east.

This possible recruitment from the south was further evidenced by the distribution of *S. fusiformis* during October 1965 (Fig. 13d) when, once again, the species was widely spread. Both stages were taken over the entire area except in the extreme east (lines 80 and 76), on the off-shore stations on the West Coast and in a tongue of water covering the outer stations of line 36, station 32-3 and the inshore stations 28-2 and 28-1. The species was also absent at stations 24-1 and 20-1, where the temperature was below 15°C at the surface (Fig. 17d). Temperatures over the distribution area were fairly uniform during October 1965, being of the order of 14-17°C between 100 m and the surface. The distribution of *S. fusiformis* was probably a result of the widespread mixed conditions and the pre-

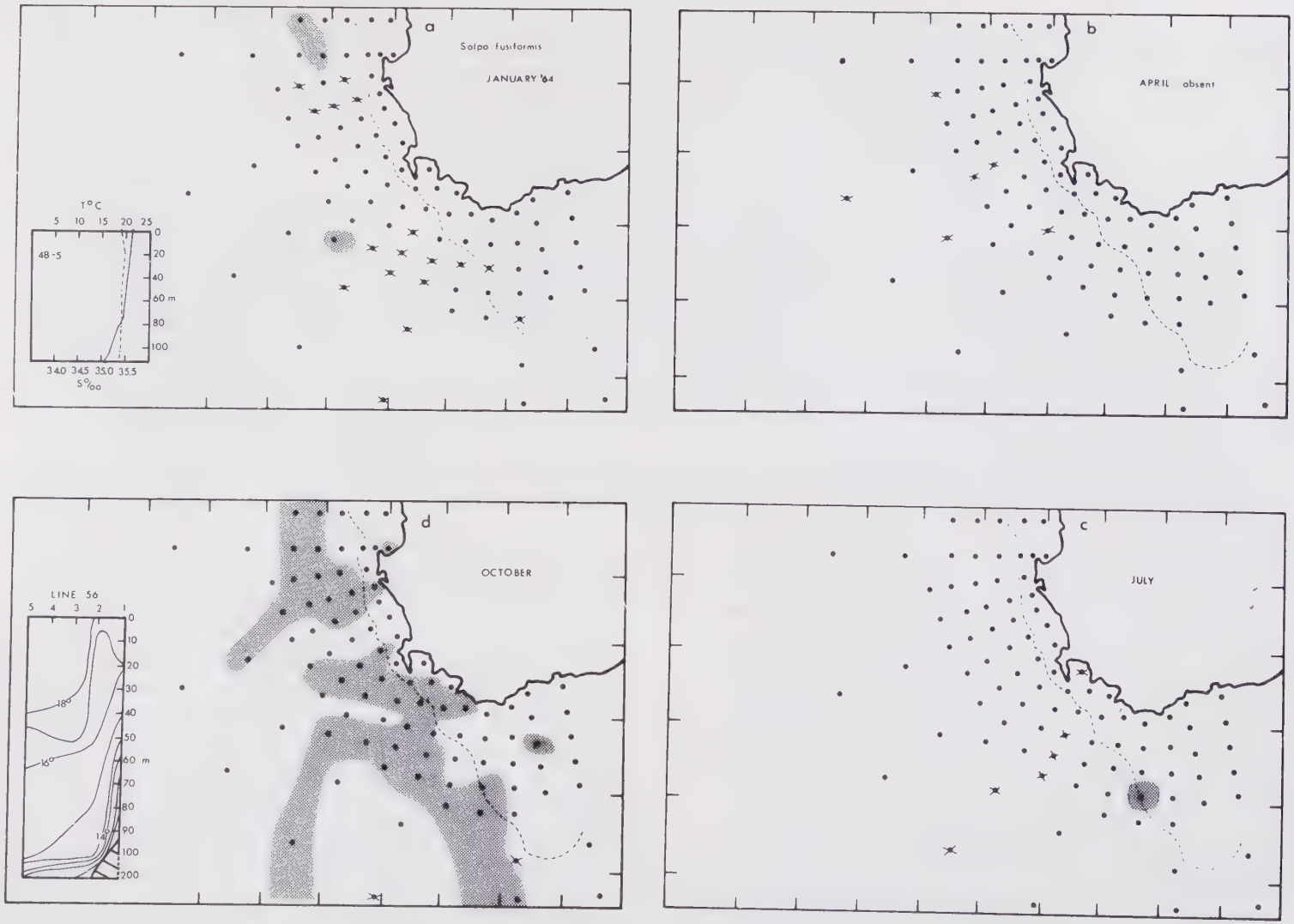

Fig. 12: Occurrence of *Salpa fusiformis* in 1964 and hydrographical parameters in selected localities

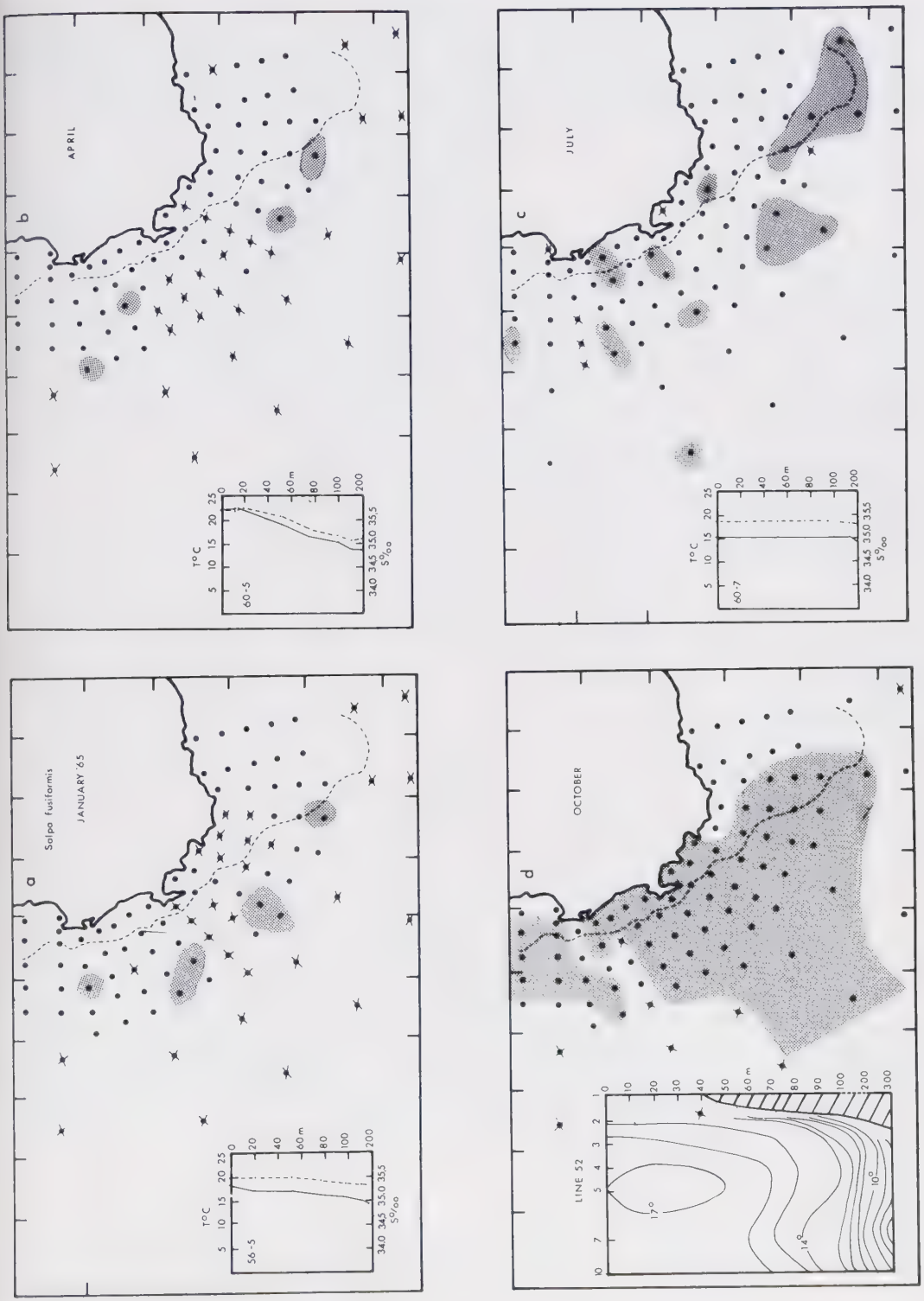

Fig. 13: Occurrence of *Salpa fusiformis* in 1965 and hydrographical parameters in selected localities

vailing south-easterly winds, which blew stronger than 16 knots for over 26 per cent of the month. Southerly winds were less common. Fairly warm, uniform conditions, e.g. along line 52 (Fig. 13d, inset), characterized the waters populated by *S. fusiformis.*

Doliolum denticulatum

A common thaliacean, this species occurred all year round and three forms were identified, viz. phorozooids, gonozooids and oozooids. Eggs were noted in some of the samples.

In January 1964 (Fig. 14a), the population, consisting mainly of phorozooids (solitary stages), was concentrated predominantly off the West Coast and in the Walker Bay area. A large gap in the distribution existed over the Agulhas Bank whilst specimens were taken on line 80. Over lines 68, 72 and 76, water temperatures generally varied between 22°C at the surface and 11°C at 100 m, and it is probably this cold, subsurface water which hindered the continuous distribution of *D. denticulatum,* a stenothermal species (Thompson 1948). The surface temperature at station 44-1, where none was captured, was 11,73°C, but at station 40-1, where considerable numbers were taken, it was 14,73°C. Isotherms along line 44 (inset, Fig. 14a) indicate strong inshore upwelling and a deep, well mixed water mass further off shore.

By April 1964, *D. denticulatum* was far more widely spread (Fig. 14b) although still absent from several of the West Coast inshore stations. Phorozooids were more abundant than gonozooids, and oozooids (nurse stages) were also captured. The surface temperatures at stations 44-1 and 40-1 were just over 14°C and no specimens were taken, whereas at 44-2 and 40-2, in surface temperatures of approximately 17-19°C, the species occurred in abundance. Warm water close inshore (Fig. 14b, inset line 80) brought with it an abundance of *D. denticulatum.*

The tendency for this species to avoid cooler inshore waters off the West Coast and on the Agulhas Bank was clearly evident in July 1964 (Fig. 14c). Temperatures close inshore between lines 20 and 40 averaged between 12 and 14°C (inset, Fig. 14c) and specimens were scarce, whereas surface temperatures above 16°C were recorded at station 2 on these lines (Fig. 16c). Gonozooids were, relatively speaking, less abundant than in January and April.

In October 1964, phorozooids still outnumbered gonozooids, although both stages were more evenly distributed (Fig. 14d). Inshore areas were still avoided, especially on the West Coast, with the exception of lines 28 and 32 where waters with a surface temperature 15°C or above extended close inshore (see Fig. 16d). Inshore upwelling affected the conditions at station 2 on line 24 (Fig. 14d, inset) and the species was absent. Recruitment appeared to be from both the south-east and the south-west.

The extremely limited areas of distribution of *D. denticulatum* in January 1965 (Fig. 15a) coincided with water temperatures of approximately 20°C at the surface and 15°C at 75 m (inset, Fig. 15a). Phorozooids were taken on ten occasions and gonozooids only four times.

During April 1965 (Fig. 15b), *D. denticulatum* was captured mainly in waters of surface temperature above 20°C over the Agulhas Bank and in waters of above 15°C on the West Coast. Close inshore, where surface temperatures were below 15°C, the species was absent (see Fig. 17b). Gonozooid and phorozooid stages were equally well dispersed. Oozooids also occurred.

The restriction placed by temperature on the distribution of *D. denticulatum* is well illustrated in July 1965 (Fig. 15c). In temperatures above 14°C, the species was abundant, and it was accordingly compressed into a narrow belt of 15°C water sandwiched between two cold water masses off the West Coast (see Fig. 17c). The distribution then fanned out over lines 24 and 20 (Fig. 15c). Very warm, uniform conditions, e.g. along line 72 (Fig. 15c, inset), characterized waters of maximum abundance. Over the southern and eastern sections of the routine area, where warmer conditions prevailed, the species was well distributed with phorozooids dominating. Oozooids were captured mainly at the outermost stations.

The absence of *D. denticulatum* in areas of colder water was also noted in October 1965 (Fig. 15d). The tongue of cold water (see Fig. 17d) extending off shore along line 40 was associated with a gap in the distribution of the species concerned. Cold water in the St Helena Bay region had a similar effect. The cooler, inshore conditions off the Cape Peninsula, e.g. 12,18°C at station 48-1, and in the Walker Bay area excluded the species, whereas well mixed, warmer waters along line 80 (inset, Fig. 15d) yielded the species in abundance. All three forms were captured but the oozooids were taken further off shore.

GENERAL

The use of planktonic organisms such as tunicates as indicator species of water masses is made easier

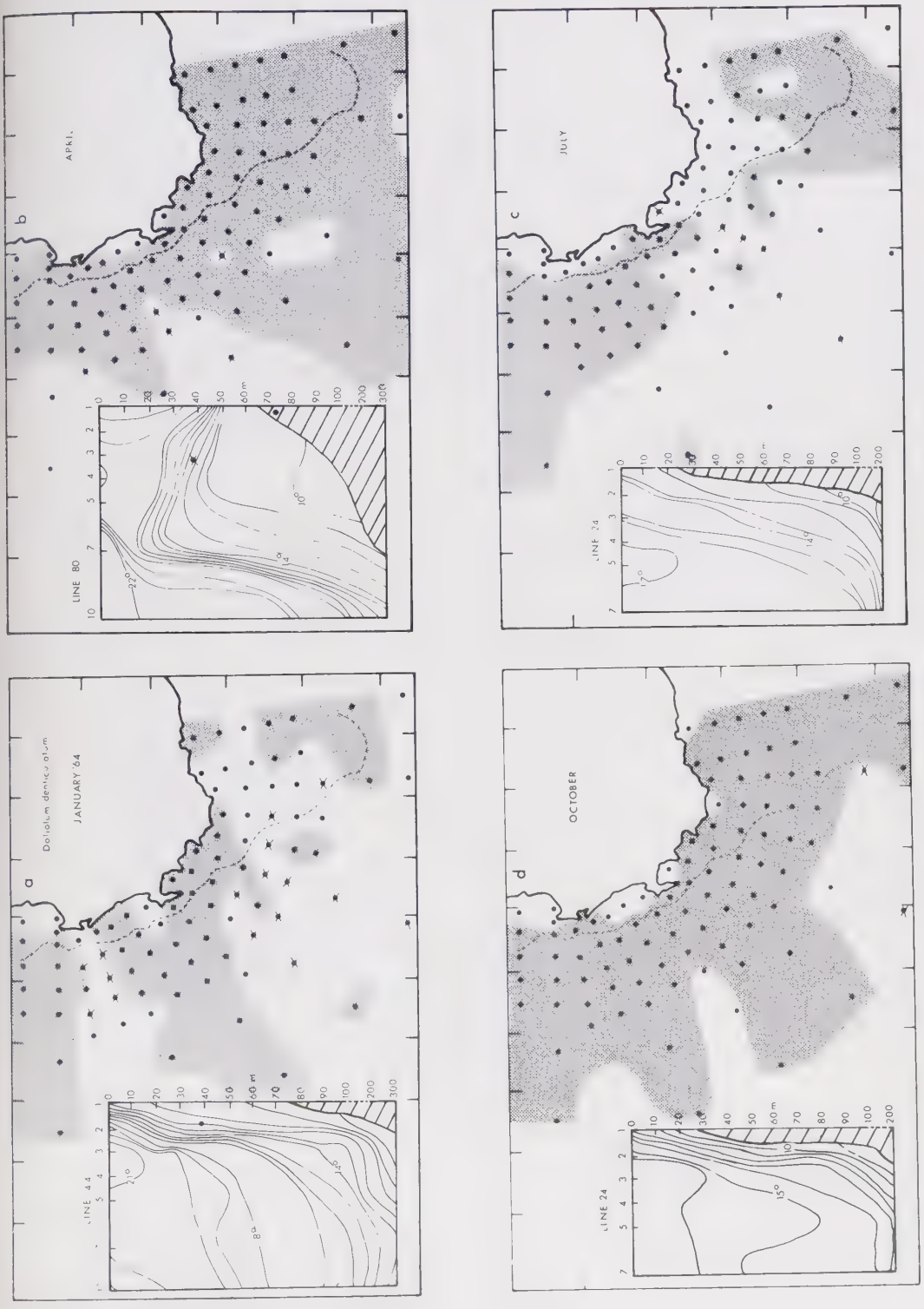

Fig. 14: Occurrence of *Doliolum denticulatum* in 1964 and hydrographical parameters in selected localities

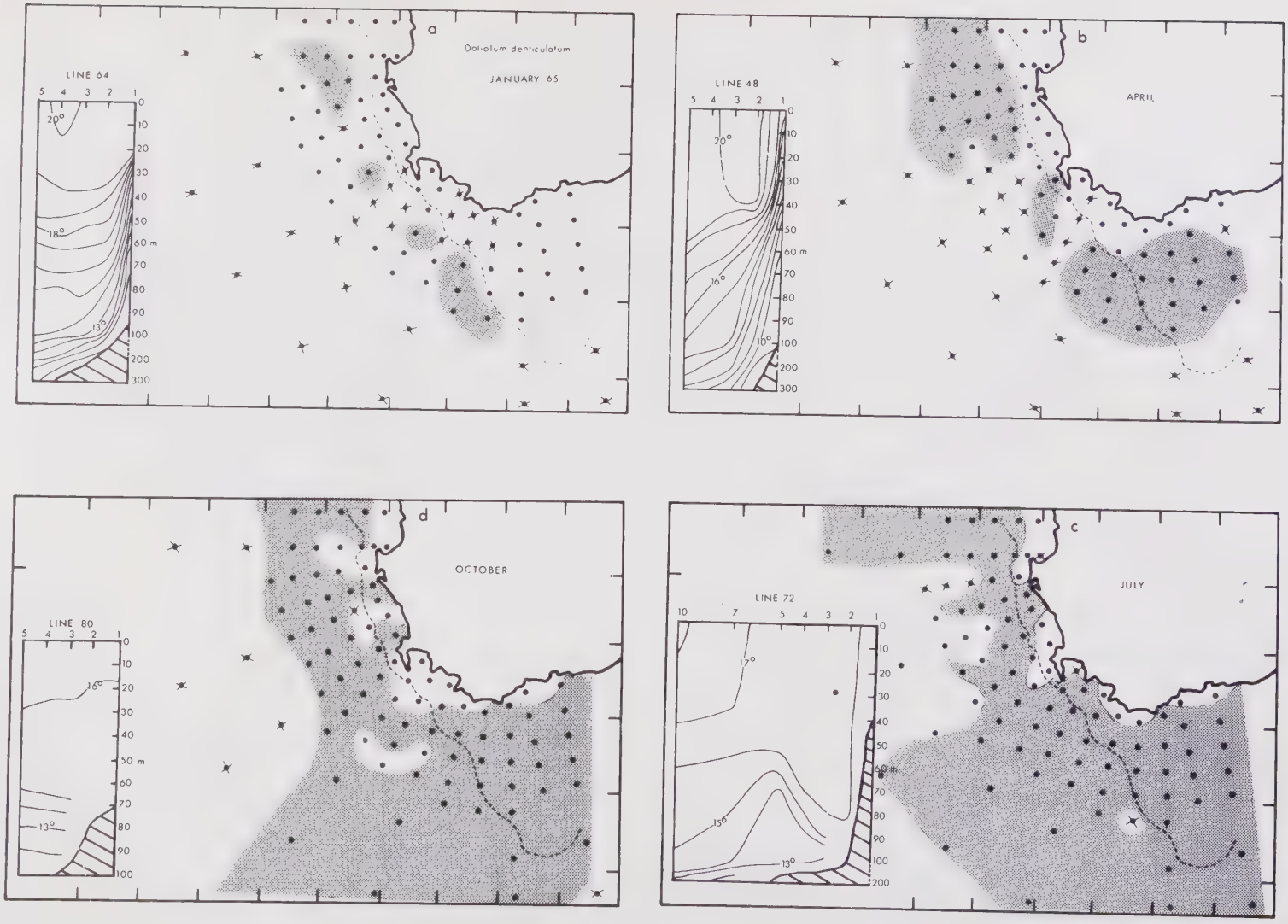

Fig. 15: Occurrence of *Doliolum denticulatum* in 1965 and hydrographical parameters in selected localities

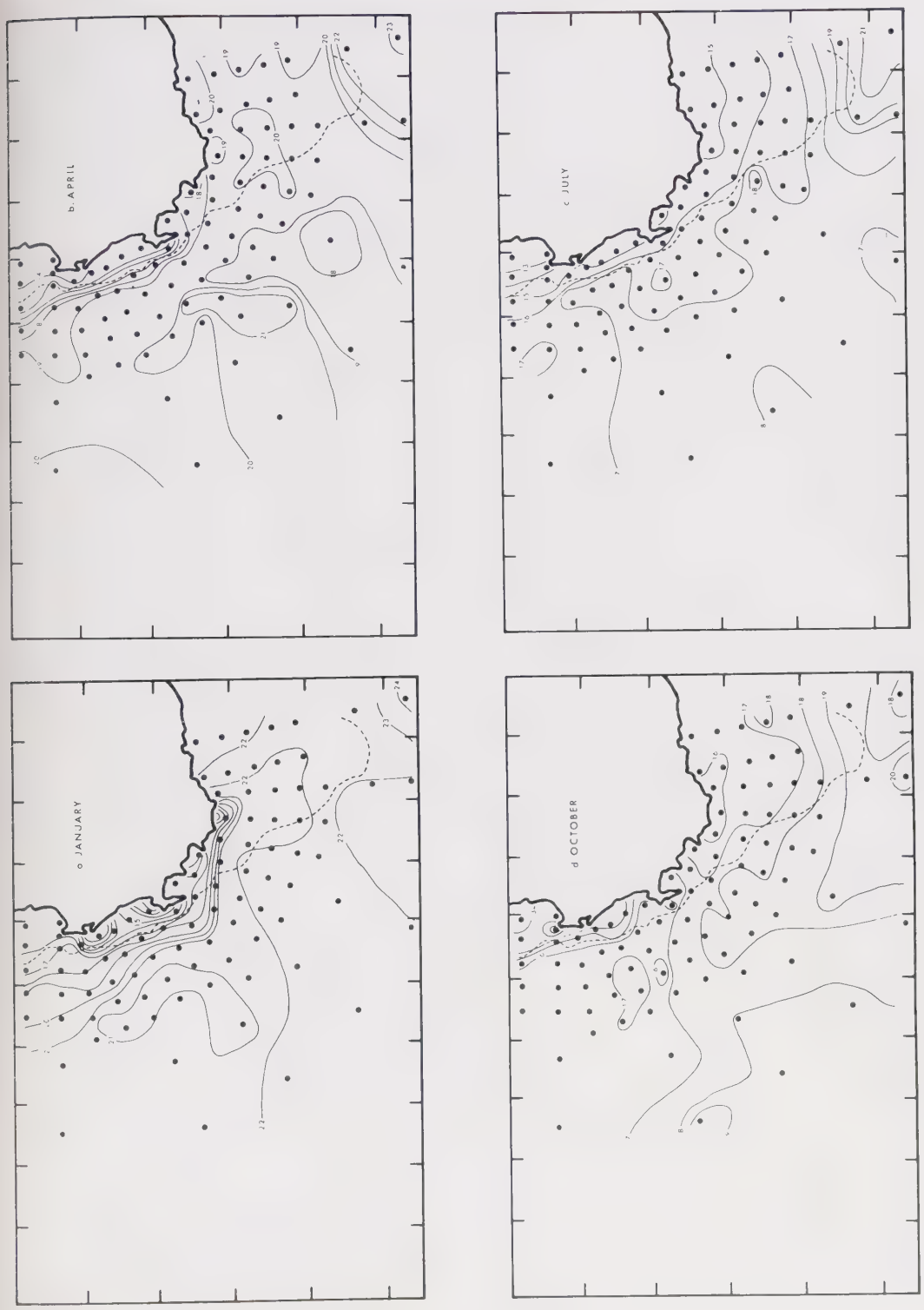

Fig. 16: Surface temperatures in the survey area, 1964

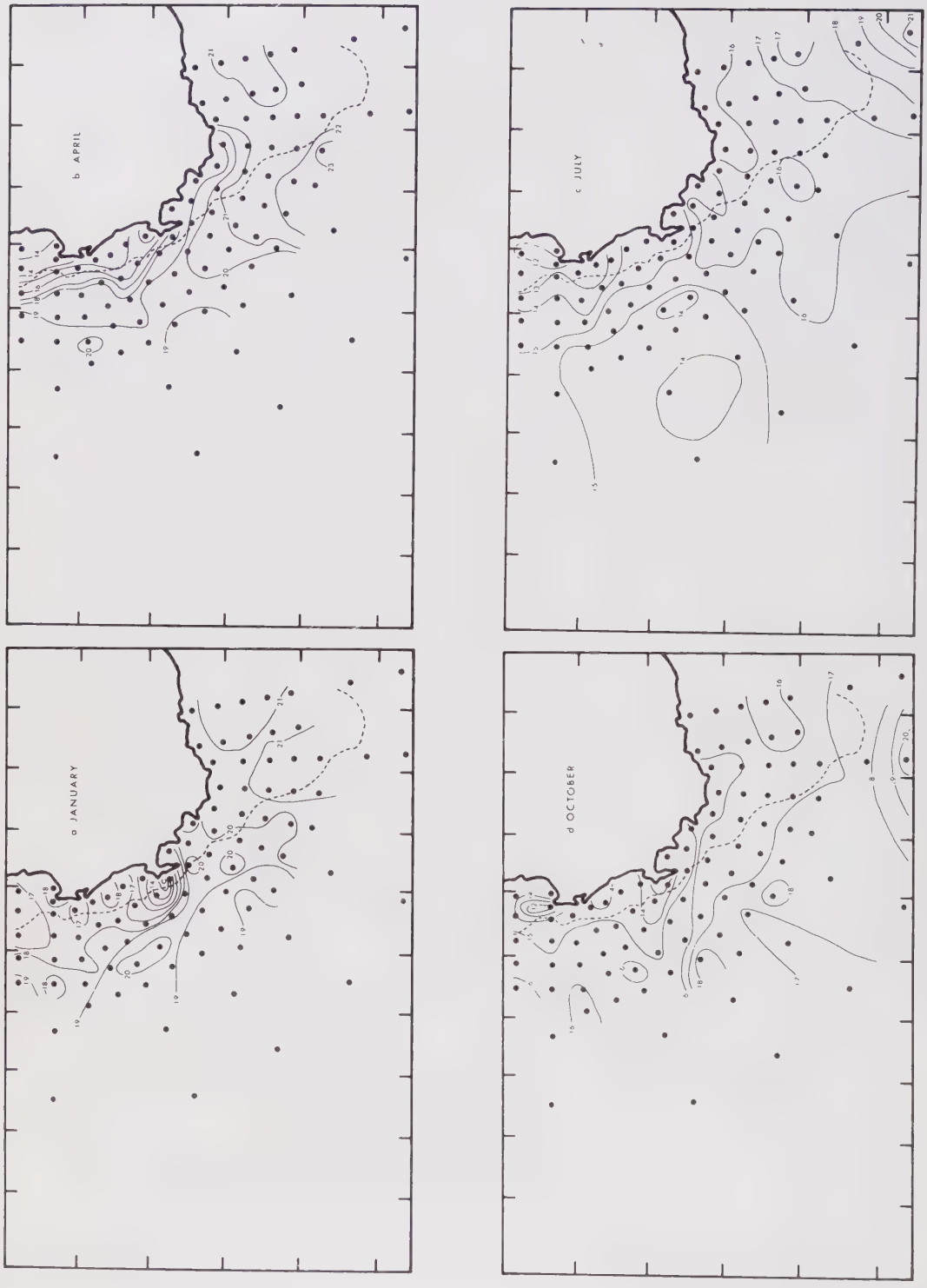

Fig. 17: Surface temperatures in the survey area, 1965

because of their relatively large size and taxonomically readily identifiable characteristics.

As indicators of Agulhas water, *Thalia democratica* and *Doliolum denticulatum* proved most valuable. The penetration of *T. democratica* northwards into the waters off the West Coast during January and April under predominantly south-easterly conditions was abruptly halted in July when north-westerly winds were at their strongest and winter conditions prevailed (see Figs. 16 and 17). It would appear that the 15°C isotherm acts as an ecological barrier to the distribution of this species.

T. democratica avoided cooler waters off the West Coast in October 1964, although specimens were taken in a water mass closely following the 15°C surface isotherm into Saldanha Bay. The penetration of Agulhas water to stations in the eastern section of the routine area, e.g. stations 80-7, 80-10 and 72-10, where warmer temperatures prevailed, brought substantial numbers of *T. democratica.* Conversely, in January 1965, *T. democratica* was scarce in cooler, subsurface conditions probably as a result of upwelling, the effects of which manifested themselves close inshore along line 48, where a surface temperature of only 11,58°C was registered at station 48-1. Patches of abundance during this month were in waters of about 20°C. In April 1965, *T. democratica* was abundant over the entire area where warm conditions prevailed, being absent only close inshore in temperatures below 15°C. When cooler conditions were encountered during July, the species was almost entirely absent. However, on the Agulhas Bank and towards line 80, the species was found in waters of 15-21°C. Warmer conditions in October resulted in a widespread distribution.

Doliolum denticulatum was found predominantly inshore towards the eastern end of the survey area but not inshore on the West Coast when upwelling was evident. Only when warmer Agulhas water (>14°C) penetrated inshore on the West Coast did *D. denticulatum* make its appearance. Off shore, in waters of warm Agulhas origin, it was regularly found, indicating its affinity for this warmer water.

Oikopleura dioica proved to be an indicator of cooler waters and occurred predominantly close inshore in upwelled waters or off shore in waters with well defined thermoclines registering temperatures of ± 10°C at 100 m and ± 20°C at the surface. As the specimens were taken in N70V hauls between 100 m and the surface, it must be assumed that the specimens captured were taken below the thermocline in the cooler waters they are presumed to characterize.

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LITERATURE CITED

BARNARD, M. 1958 — Systematique et distribution saisonnière des Tuniciers pelagiques d'Alger. *Rapp. Commn int. Explor. scient. Mer mediterranée* **14**:211-231.

DE DECKER, A. H. B. 1973 — Agulhas Bank Plankton. In *The Biology of the Indian Ocean.* Zeitzchel, B. (Ed.). Berlin; Springer: 189-219,

FENAUX, R. 1963 — Écologie et biologie des Appendiculaires mediterranéens (Villefranche-sur-Mer) *Trav. Stn zool. russe Villefranche* **22**(15):142 pp. (*Vie Milieu Suppl.* **16**).

FURNESTIN, M. L. 1957 — Chaetognaths et zooplancton du secteur atlantique Morocain. *Rev. Trav. Inst. Pêch. marit.* **21**(1-2):1-356.

KEMP, S. and A. C. HARDY 1929 — Objects, equipment and methods. 2. The ships, their equipment and the methods used in research. *"Discovery" Rep.* **1**:181-204.

LAZARUS, B. I. 1974 — The inshore zooplankton of the Western Cape. Ph.D. thesis, University of Stellenbosch: 300 pp + 72 Figs.

THOMPSON, H. 1948 — *Pelagic Tunicates of Australia.* Melbourne, CSIRO Australia: 196 pp. + 75 plates.

TOKIOKA, T. 1960 — Studies on the distribution of appendicularians and some thaliaceans of the North Pacific, with some morphological notes. *Publs Seto mar. biol. Lab.* **8**(2):351-443.

VAN ZYL, R. P. 1960 — A preliminary study of the salps and doliolids off the west and south coasts of South Africa. *Investl Rep. Div. Fish. S. Afr.* **40**:31 pp.

FISHERIES BULLETIN 12
1979
VISSERYE-BULLETIN 12

CONTENTS/INHOUD

BEST, P. B. and P. D. SHAUGHNESSY — An independent account of Captain Benjamin Morrell's sealing voyage to the south-west coast of Africa in the *Antarctic*, 1828/29 1

SHAUGHNESSY, P. D. and A. I. L. PAYNE — Incidental mortality of Cape fur seals during trawl fishing activities in South African waters 20

PAYNE, A. I. L. — A survey of the stock of the southern African West Coast sole *Austroglossus microlepis* between 28°30′S and 32°S .. 26

NEPGEN, C. S. DE V. — Trends in the line fishery for snoek *Thyrsites atun* off the South-Western Cape, and in size composition, length-weight relationship and condition 35

DA FONSECA BAPTISTA, S. R. — Changes in abundance of albacore *Thunnus alalunga* and yellowfin *T. albacares* off southern Africa, 1969-1976 44

VENTER, J. D. — 'n Verbeterde tegniek vir die brand van heel otoliete 49

LE CLUS, F. — Oocyte development and spawning frequency in the South West African pilchard *Sardinops ocellata* 53

DE VILLIERS, G. — Recovery of a population of white mussels *Donax serra* at Elands Bay, South Africa, following a mass mortality .. 69

POLLOCK, D. E. and C. J. DE B. BEYERS — Trap selectivity and seasonal catchability of rock lobster *Jasus lalandii* at Robben Island sanctuary, near Cape Town 75

BOYD, A. J. — A relationship between sea surface temperature variability and anchovy *Engraulis capensis* recruitment off South West Africa, 1970-1978 80

ROBERTSON, A. A. — Adaptations permitting aimed trawling with rectangular midwater trawls from non-fishery research vessels .. 85

LAZARUS, B. I. and D. DOWLER — Pelagic tunicata off the west and south-west coasts of South Africa, 1964-1965 93